1699

Bulletin No. 41

1914

Agricultural Research Institute, Pusa

The use of sweet jowar (sorghum Sp.) as a source of commercial sugar or as fodder and the variation in composition of the crop during growth.

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1914

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Superintendent Government Printing, India, Calcutta

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The use of sweet jowar (sorghum Sp.) as a source of commercial sugar or as fodder and the variation in composition of the crop during growth.

Introduction.

FROM time to time attempts have been made to grow sweet varieties of jowar in India for the purpose of sugar production.* The seed has in many cases been imported from America but in certain parts of India local varieties are found which contain much sugar. Watt† states that, in Bikanir and Ajmir, a form of sugar-yielding sorghum, designated the Alipura, has been known and cultivated from time immemorial and used in the preparation of the sugar candy, for which these towns are famed. Watt further states that, in 1890, an official enquiry in the Punjab resulted in the report that while in Ferozepur, Sialkot and elsewhere sweet sorghums were known, the saccharine property was lost after a few years' cultivation in other districts, to which these plants had been experimentally conveyed.

Whilst the writer was acting as Agricultural Chemist, Punjab, in 1912, he received several enquiries as to the use of this crop for sugar production. Accordingly he took the opportunity of making a detailed investigation of the question. It has been thought worth while to put the results on record.

The Industry in the United States :—It will perhaps not be out of place to mention a few facts relating to the production of sugar from Sorghum (Jowar) in the United States of America. The writer is indebted, for most of his information relative to that country, to Farmer's Bulletin No. 477 of the United States Department of Agriculture, 1912. That the industry is of some importance there will be recognised by the fact that in 1899 at least 17,000,000 gallons of sorghum syrup were

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* Poona Farm Report, 1895.

† The Commercial Products of India, page 1041.

produced. When the extension of the sorghum sugar industry was first advocated in the States, it was thought that this crop would play a notable part in supplying the nation's sugar, on account of its wider distribution than sugar cane or sugar beets, its large yield per acre and ease of cultivation, and its rather high sucrose content. After many trials, however, it was found that the juices, although rich in sucrose, contained some reducing sugars and also quite a large percentage of gums and gummy materials, which on concentration prevented crystallisation. After these experiments were made the question of using sorghum for sugar and syrup manufacture was dropped to a great extent until more recently, when the manufacture of sorghum syrup has been in a measure revived.

The people consume the syrup and it is to be noted that very little, if any, solid sorghum sugar is manufactured to-day in America.

History of sorghum.—For this the reader is referred to the History and Distribution of sorghum in Bulletin No. 175 of the Bureau of Plant Industry, United States Department of Agriculture. The first efforts to manufacture sugar and syrup from sorghum were made in the United States, where sweet sorghum was first grown in 1853 from Chinese Sorgo, the seed of which was obtained from France. In 1857 about 16 varieties of African sorghum were introduced into America, and these as a class were called "Imphee".

Varieties of sorghum.—In America, Ball has divided the sweet sorghum varieties into three or four groups, *e.g.*, the amber, orange, sumac and gooseneck sorghums.

The number of varieties is very great.

In India no classification of the saccharine jowars exists and in the work described in this paper no attempt has been made to name varieties. Of the exotic forms, the amber and the collier seem to have attracted most attention in India.*

Experimental work.—The results obtained below were obtained from plots grown at Lyallpur and at Gurdaspur, Punjab, respectively. In the former case Mr. D. Milne, Economic Botanist, Punjab, kindly provided the land and grew the crop. I am indebted to Mr. H. Southern, Deputy Director of Agriculture, for growing the crop at Gurdaspur.

In general the experiments were planned to elucidate the following points :—

1. The total yield of sugar per acre in the crop.
2. The total yield of gur or raw sugar obtainable per acre.

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* Watt—The Commercial Products of India, page 1041.

3. The quality of the gur obtained.
4. The stage at which the crop should be cut in order to yield the maximum amount of sugar.
5. The total weight per acre of the crop if cut for fodder.

The seed was obtained from an agriculturist near Lyallpur, who grows a fair amount of this crop.

Lyallpur.—An exceedingly good and even crop was obtained.

Date of sowing . . .	26th July 1912.
Seed rate	12 lbs. per acre.
Previous treatment of land .	The land had been fallow for a year and during that period it received two deep ploughings, two shallow ploughings with the *Desi* plough, and two harrowings.
Manure	None applied.
Irrigations	Four, ~~o[illegible]~~ on 28th August 1912, 30th September 1912, 17th September 1912, 3rd November 1912.
Total area	one-tenth acre.

Gurdaspur.—Half an acre was grown for experiment but owing to difficulty of obtaining seed it was sown late. The late sowing, combined with the fact that the land was very low lying, resulted in a very poor crop. No data could be obtained as to the yield per acre but the crop afforded material for examining the sugar content at different stages of growth.

Results.

Lyallpur.—The total area of the plot was here $\frac{1}{10}$ of an acre and it measured 212 ft. long by 20 ft. broad. It is well known how difficult a matter it is to obtain samples of a cane crop which are representative of the whole area. The same difficulty applies to Jowar.

The whole plot was first of all divided into 20 equal sections as shown in the diagram.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

The crop on 1 was reserved for seed purposes. On 30th September the whole of the crop on 2 and 11 was cut, weighed, stripped and again

weighed, crushed and the juice weighed and analysed and then boiled into sugar. The figures for section 2 were kept separate from those for section 11 so as to have duplicate determinations.

On 7th October the crop on sections 3 and 12 was similarly treated.

Thence onward the rest of the crop was divided into sub-sections each 1/1000 of an acre in area and these strips were numbered beginning from plot 4.

On the 16th October duplicate samples were cut and examined exactly as above. One of these samples consisted of the sub-sections numbered 12, 28, 44 and the other of sub-sections 4, 20, 36 so that each sample consisted of 3/1000 of an acre taken at 3 widely different parts of the main plot.

At intervals, during the growth of the crop similar duplicate samples were taken until by the time the crop was dead ripe, most of it had been cut.

The general results are collected together in the accompanying table at page 5.

Boiling the juice.—The juice was boiled down in a shallow iron pan and the dried megass was used as fuel. As a clarifying agent a watery extract of a local mucilaginous plant (vernacular *Suklai*) was added to the boiling liquid. All scum was carefully skimmed off and a fine golden yellow clear liquid finally obtained. In none of the earlier boilings were we able to obtain a solid product, even when the concentrated liquid was left for some weeks. This is not surprising when we turn to the analyses of the earlier juices on page 5 where it will be seen how high the glucose ratio is.

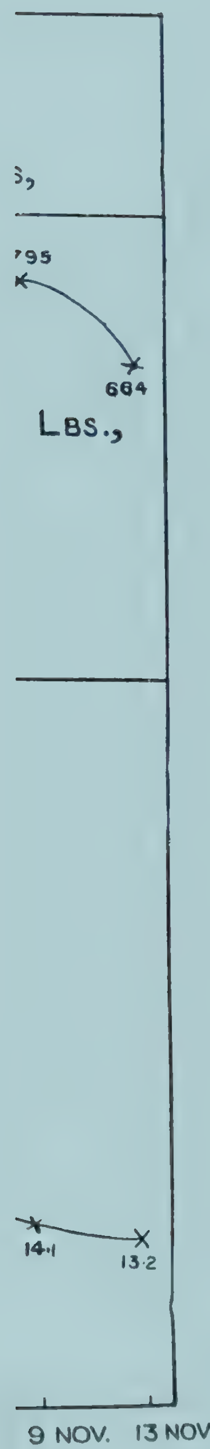
On the 9th November 1912 we met with some success. The sample boiled represented the juice from 1/50 acre. It took 2 hours to boil the liquid down to the proper density. The syrup was then poured into the usual earthenware pot and was found to weigh 17·5 lbs. The juice from which it was obtained weighed 131·75 lbs. So the gur obtained works out at 13·3% of the weight of the juice or 875 lbs per acre.

The gur set to a fairly solid mass and after 2½ months was analysed. It then contained a fair amount of crystals.

The analysis shewed it to contain sucrose 57·90% and reducing sugars 13·42.

This is quite a poor quality gur.

Gurdaspur experiments.—For the sampling, the plot was divided into a series of strips which were cut at various intervals of time throughout the year. At each cutting duplicate strips were cut and the crop kept


795
664
LBS.,
14.1
13.2
9 NOV.
13 NOV

LYALLPUR.

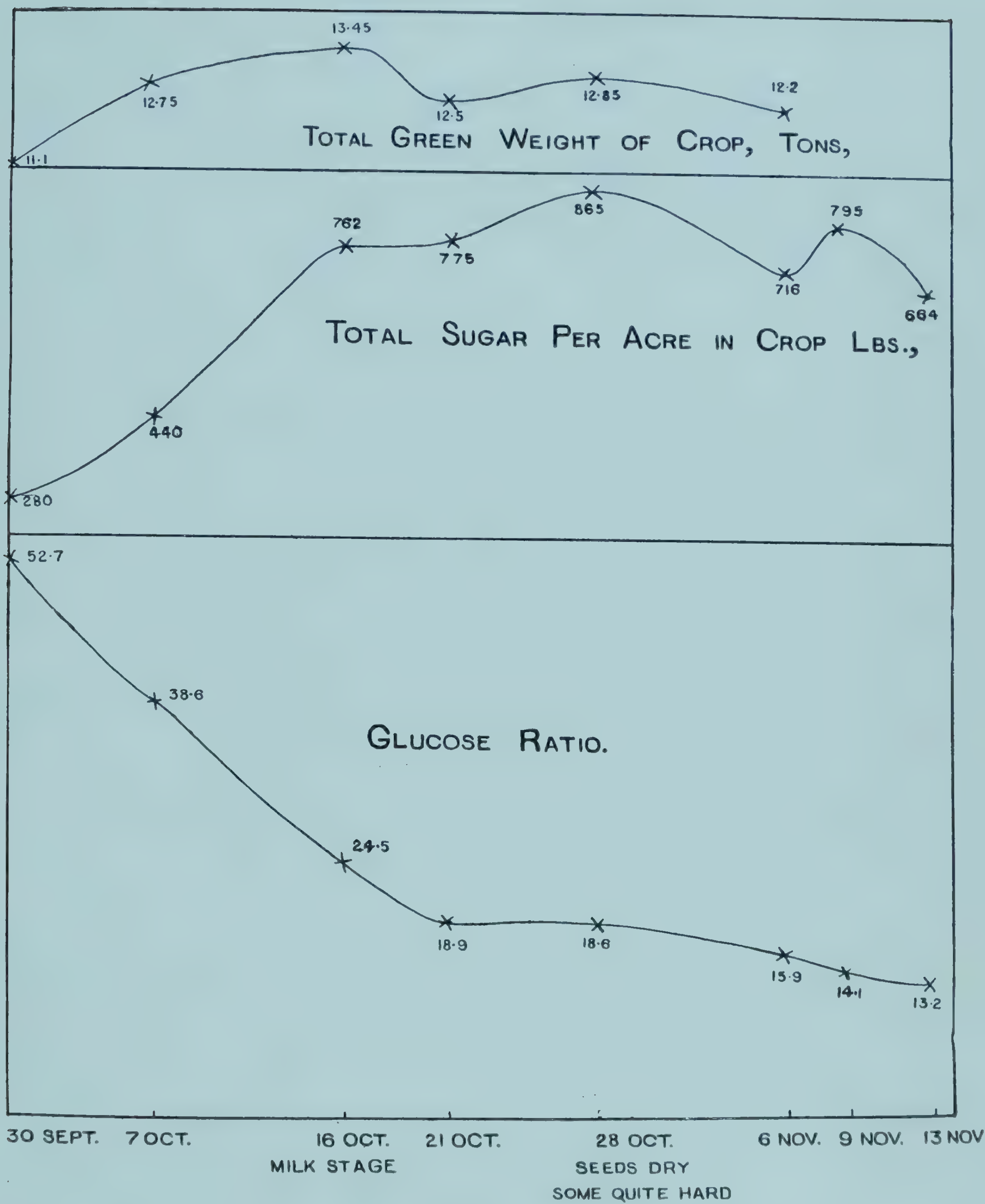


CHART No. 1.

GURDASPUR

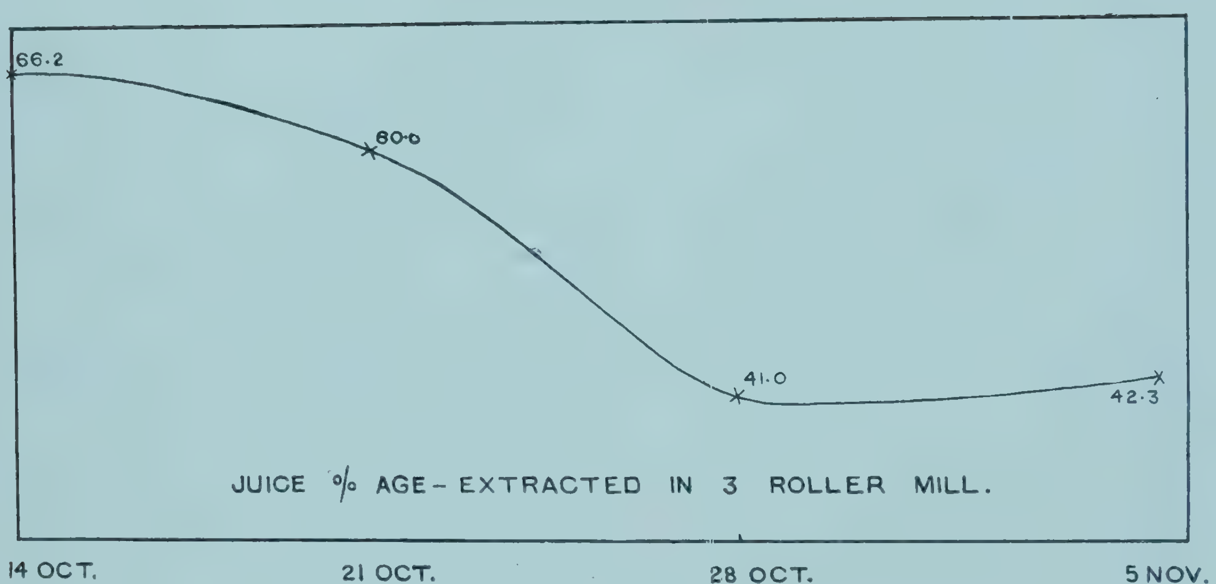


CHART No. 2.

separate in each case. Three dozen plants were taken from each sample and were sent overnight to Lyallpur where they were analysed early next morning. Thus at each cutting duplicate samples were analysed. These duplicates are shewn as A and B in the table which collects together the results obtained.

Date of sampling.	Sample.	Number of canes.	Total weight, lbs.	Weight stripped.	Weight of juice.	% juice—one extraction in 3—roller bullock mill.	Composition of Juice.				Total sugar in juice extracted lbs. Average A and B.
							Specific gravity.	Sucrose % gms. per 100 c. c.	Reducing sugar % gms. per 100 c. c.	Total sugar % gms. per 100 c. c.	
14th Oct. 1912	A	36	12·25	6·25	4·5	72·0	1·0498	4·09	6·80	10·98	0·52
	B	,,	15·0	8·0	5·0	62·5	1·0577	5·85	6·14	11·99	
21st ,, 1912	A	,,	15·0	7·5	4·5	60·0	1·0645	7·82	5·51	13·33	0·62
	B	,,	15·75	8·75	5·25	60·0	1·0680	9·10	4·52	13·62	
28th ,, 1912	A	,,	16·0	8·5	3·75	42·1	1·0750	11·46	3·11	14·57	0·46
	B	,,	14·5	7·5	3·0	40·0	1·0757	11·45	3·30	14·75	
5th Nov. 1912	A	,,	14·5	6·0	2·5	41·7	1·0760	11·08	3·41	14·49	0·31
	B	,,	13·5	5·25	2·25	42·9	1·0707	10·41	3·13	13·54	

Attempts were made to prepare gur from the juice at various intervals during the growth of the crop. The earlier attempts were quite unsuccessful.

On 23rd October 1912 some gur was obtained but it was very weak and watery and was of little value. On the 5th November 1912 a semi-solid gur was obtained. The taste and colour of the product were however offensive and cattle would not eat it. It was not analysed.

Relation of degree of distinctness of mid rib of leaf to amount of sugar in the stem.—A common belief prevails among the cultivators that plants having a plain white mid rib are less sweet than those in which the mid rib is more or less inconspicuous.

A few analyses were made to test the point. Plants were collected from the same plot, some having distinct white mid ribs, and some having indistinct mid ribs. No obvious connection could be traced between the amount of sugar in the juice and the distinctness of the mid rib.

The four analyses quoted below tend to indicate that plants whose leaves have an indistinct mid rib have a slightly higher sugar content than those whose mid rib is white and distinct. Since however the two sets of plants in each experiment were taken from two different varieties of jowar the results are open to objection. They are quoted chiefly with the idea of shewing the sugar content of certain well recognised local varieties.

Date.	Variety.	Description.	Sucrose in juice gms. per 100 c. c.	Invert sugar in juice gms. per 100 c. c.	Total sugar gms. per 100 c. c.
22nd Oct. 1912	Double grained—Lyallpur.	White mid rib thick stemmed.	8·80	2·19	10·99
	Plants taken from experimental plot at Lyallpur.	Indistinct mid rib thick stemmed.	11·78	2·27	14·05
	Double grained—Lyallpur.	White mid rib thin stemmed.	10·60	2·13	12·73
	Sweet—Local	Indistinct mid rib thin stemmed.	10·58	2·49	13·07

The sugars present in sorghum.—Unfortunately want of time prevented a very complete examination into the kinds of sugar present in the juice expressed from sorghum. Osazones were however prepared from the juice by the use of phenylhydrazine hydrochloride and sodium acetate. An examination of the osazone microscopically and determination of its melting point shewed that it consisted wholly of glucosazone. Hence it is improbable that any other sugars than cane sugar, dextrose and lævulose are present.

Conclusions.

I. The experiments shew that as a source of sugar saccharine jowar is not worth growing in India. Even in America it is only grown to make syrup for which there is a demand in that country, and which would have to be created in India.

The high glucose ratio of the juice militates against the production of good crystalline gur. The juice contains also substances which produce at times a very objectionable taste in the gur.

Apart from the great difficulty in preparing the gur the yield per acre obtained from a very good crop of jowar in these experiments only worked out at about 8 cwt. Hence the yield of sugar per acre would be only about 1/3 of that from the average country sugarcane crop.

In experiments at Poona,* with the exotic sorghum varieties, collier and amber, very similar yields were obtained, *viz.*, 1,174 lbs. and 1,072 lbs. of molasses per acre from the collier and amber variety respectively.

II. The experiments indicate that the total sugar content of the crop is highest when the seed contents begin to dry (see chart No. 1). Thereafter until the seeds are dead ripe the total sugar in the crop decreases but its decrease is mainly at the expense of the reducing sugar, and hence the glucose ratio seems to decrease as ripening proceeds (see chart No. 1).

III. The Gurdaspur data shew that as the plant approaches ripeness, the amount of juice expressed from it decreases (see chart No. 2).

IV. As a source of fodder saccharine jowar seems valuable and in this connection the reader may be referred to U. S. A. Farmer's Bulletin No. 246 entitled "Saccharine sorghum for Forage" by Carleton R. Ball. The crop is fairly quick growing and the table on page 5 shews that on our plot at Lyallpur we obtained 13 tons of total green produce per acre. The data in the same table (see also chart No. 1) shew that after the seed is in the thin milk stage no increase in total weight of the crop takes place and also the amount of total sugar in the crop has almost reached its maximum. Hence the crop, when being cut for fodder, should not be allowed to get beyond this stage. Further beyond this stage the nutritive value of the crop as fodder decreases.

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*Poona Farm Report, 1895, 9.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 42 1914

Agricultural Research Institute, Pusa

Notes on Cane Crushing in the United Provinces

BY

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Notes on Cane Crushing in the United Provinces.

To be able to form a reasonably accurate judgment of a variety of sugar cane and of the possibility of its succeeding as a field crop in any tract, it is necessary to possess accurate information on a number of points based on observations made in the field, in the laboratory, and in the mill. It is necessary to observe in the field the general crop characters ; in the laboratory the sugar content and quality of the juice, and in the mill what proportion of the juice and total sugar can be extracted, and the cost of doing so.

These points are of equal importance in successful cane cultivation. It is of no special advantage to handle an enormous weight of cane, if the juice is of poor quality, and it is of no use selecting a cane because of the abnormally high sucrose content of its juice, if the amount and nature of the fibre is such that it is impossible to extract a good proportion of it.

It thus often happens that the most profitable cane is one which presents no exceptional features in any one respect, but a combination of moderately good qualities.

The behaviour of sugar cane, when subjected to pressure between the iron rollers of the mill for the purpose of extracting the juice may be conveniently termed the " milling property." This property is the resultant of several factors and can be determined.

It is proposed to discuss in this bulletin some observations on this point which have been made during the last three years at the Experiment Stations at Partabgarh and Shahjahanpur.

It is obvious to any one who has observed the local conditions during the cane harvest that crushing by bullock power imposes a very severe strain on the cultivator's resources, and acts probably more than any other cause against a large extension of the area under cane in these provinces. With the price of up-country gur at the present rates, it is unlikely that there will be any immediate increase in the number of factories manufacturing white sugar in the Upper Doab. The prospect of any increase in their number at any time is small, unless the area under cane is considerably extended.

Any increase in area will be gradual depending in the authors' opinion, on the introduction of some cheaper and quicker way of dealing

with the produce for the manufacture of gur, within the reach of the smaller landholders and co-operative societies. The present crop is as much as the bullock power of the provinces can deal with, and the area will not increase permanently to any appreciable extent unless some cheaper form of crushing than bullock power is introduced.

It will be pointed out later on that many of the canes of the United Provinces can yield a high proportion of their total sugar on crushing in powerful bullock mills, but at a cost in bullock power that is entirely beyond the reach of every-day agricultural practice. A considerable impetus would be given to the extension of the area under cane if a suitable small power mill for crushing cane for gur manufacture could be introduced. It is not necessary to aim immediately at the high extraction and efficiency obtained in the large mills of factories equipped with modern plant; or of countries where the sugar industry is highly organised. An extraction no higher than that given by the best type of bullock mill, would be sufficient; but it is essential to deal with the produce at a reasonable rate and at a reasonable cost, and to relieve the cultivator of the strain resulting from the present system of crushing by bullock power.

In considering the question of crushing, the following terms are used which need some explanation :—

(*a*) Extraction.
(*b*) Juice expressed per 100 cane.

(*a*) Extraction means the percentage of the total cane sugar or sucrose in the cane that passes into the juice on crushing, or the sugar extracted per 100 parts of total sugar in the cane.

(*b*) Juice expressed per 100 cane is the weight of juice obtained from 100 parts by weight of cane—a figure obtained in these experiments by direct weighing.

When cane is crushed, it is divided into two parts, juice and bagasse, or khoya, which is used afterwards as fuel for evaporating the juice. Both the juice and bagasse contain sugar, and the object of cane growing and crushing, whether for the production of gur or the manufacture of white sugar, is to get as much juice, and as little bagasse as possible, and to see that little sugar is left in the bagasse.

A numerical example will probably make the meaning of the term extraction clear to those readers, who are not familiar with the terminology of sugar manufacture. 100 mds. of a certain variety of cane, on crushing in a 3 roller bullock mill, yielded 75 mds. of juice containing

15·5 per cent. of sugar or sucrose, and 25 mds. of bagasse or khoya containing 6·4 per cent. sucrose.

100 mds. cane =75 mds. juice containing $\frac{75 \times 15 \cdot 5}{100}$=11·6 mds. sugar.
100 mds. cane =25 mds. khoya containing $\frac{25 \times 6 \cdot 4}{100}$=1·6 mds. sugar.
100 mds. cane contained 11·6+1·6 mds. sugar=13·2 mds. sugar.

Of the total 13·2 mds. sugar 11·6 mds. or $\frac{11 \cdot 6 \times 100}{13 \cdot 2}$ per cent. or 87·9 per cent. had passed into the juice on crushing, and was available for sugar or gur making, and $\frac{1 \cdot 6 \times 100}{13 \cdot 2}$ per cent. or 12·1 per cent. was left in the bagasse, or khoya, and lost. In this case the extraction was 87·9, that is 87·9 per cent. of the total sugar in the cane had been extracted in the juice. The juice expressed per 100 of cane was 75.

In sugar factories, employing plant of modern design, the cane is passed through what are really a series of different mills, and the bagasse, before being finally burnt, is mixed or macerated with warm water (varying in amount acccording to the conditions) and again crushed. By this means some sugar is washed out of the bagasse, and a very high extraction can be secured. The average figure published by the mutual control of Java Factories for 10 years is over 90.

With the exception of the cane used by factories, which, at the present time, are few in number, the cane grown in the United Provinces is crushed by bullock mills of various designs and efficiency, some with 3 rollers, and some with 2 rollers.

From the statements made above it will be seen that with single dry crushing (that is crushing as practised by the cultivators using iron bullock mills, without macerating the bagasse with water), the extraction obtained depends on—

(1) the quality of cane,

(2) the quality of the bagasse or khoya.

If the cane contains a large amount of fibre, the quantity of juice will be proportionately less, and the quantity of bagasse greater. In addition to the quantity of fibre, the quality or kind of fibre is an important factor in determining the amount of juice retained in the bagasse. This was pointed out by Somers—Taylor (Bulletin 37, Agricultural Research Institute, Pusa), who examined the bagasses of the different varieties in the collection of canes at Sabour. For any one variety of cane with the same kind of fibre the quality of the bagasse, in the case of single crushing, depends entirely on the mill.

The following treatment of the subject makes the point clear :—

If

$\mathbf{f}$=weight of fibre per unit weight of cane ;
$\mathbf{m}$=weight of fibre per unit weight of bagasse ;
$\mathbf{x}$=weight of bagasse per unit weight of cane ;

the total juice per unit weight of cane$=\mathbf{1-f}$
the expressed juice per unit weight of ~~bagasse~~ cane$=\mathbf{1-x}$
the juice left in unit weight of bagasse$=\mathbf{1-m}$
the juice in $\mathbf{x}$ parts of bagasse or the juice left in bagasse per unit weight of cane$=\mathbf{x(1-m)}$
the total juice in the cane=the expressed juice+the juice left in the bagasse.

$$\mathbf{1-f=1-x+x(1-m)}$$

$$\mathbf{x}=\frac{\mathbf{f}}{\mathbf{m}}$$

In canes with the same kind of fibre, the quantity of bagasse obtained on single crushing will be small when the fibre ($\mathbf{f}$) in the cane is small, and fibre in the bagasse ($\mathbf{m}$) is large, that is, when a good cane is well crushed. The quantity of bagasse will be large when the fibre ($\mathbf{f}$) in the cane is large and the fibre ($\mathbf{m}$) in the bagasse small, that is, when a poor cane is badly crushed.

Many factors have to be taken into consideration in determining the value of a cane for any particular locality, such as, yield of sugar per acre, period of ripening, etc., but amongst them the extraction obtained on single dry crushing is important.

Different varieties of cane vary in the amount of fibre they contain, and the quality of bagasse they yield, and consequently in "extraction," which is the resultant of these two factors. Taylor (*loc. cit.*) has pointed out that the variation in the quality of the bagasse is probably due to differences in the nature and structure of the compound celluloses, that make up the tissues or fibre of different varieties of canes, and may be a definite character of certain varieties. This is a distinct advance on our present conceptions, and will be of great use in valuing canes. The quantity of fibre in the cane is of equal importance. These factors, the quality of the bagasse, and the fibre content of the cane, find expression in the term "extraction," which can be also calculated from the formula $1{\cdot}03\,\frac{\mathbf{(m-f)}}{\mathbf{m(1-f)}}$ where $\mathbf{f}$ is the fibre per unit weight of cane, and $\mathbf{m}$ the fibre per unit weight of bagasse. This combined factor expressing both the quality of the bagasse yielded on single dry crushing under definite con-

ditions, and the fibre content of the cane, will probably prove the most useful of any in assigning relative values to new cane varieties from a milling point of view.

As far as the authors are aware no comparative tests of canes grown in the United Provinces have been made with reference to their behaviour on crushing in a 3 roller iron bullock mill, nor has the quantity of cane crushed per hour, and the extraction obtained by the use of the latter mills been determined under conditions of strict chemical control. These are important points in determining the price at which it would become profitable to sell canes to factories.

The experiments conducted at Partabgarh and Shahjahanpur during the last three seasons have given a large number of results, from which information on these points can be obtained. The work was carried out with one of the best type of 3 roller bullock-driven mills on the market, with 8″ rollers manufactured in India, and costing Rs. 110. The method of experiment was (1) to crush in five mills working simultaneously a certain weight of cane, slightly over two tons for each variety examined, (2) to weigh the juice and determine the amount of sugar (sucrose) in it, (3) to sample the bagasse from each mill and to determine the sucrose in it at intervals of one hour.

From these data the extraction can be calculated. The detailed figures of each experiment are not published, but an explanation of two is given here to make the method of calculation clear. Taking Reora of Benares, an indigenous variety very popular in the eastern districts and Ashy Mauritius, a variety imported, the following figures were obtained :—

Name of cane.	Weight of cane crushed each sample (lbs.).	Weight of juice obtained (lbs.).	Juice expressed per 100 cane.	Sucrose in juice per cent.	Sucrose in bagasse per cent.	Bagasse per 100 cane.
Reora	1434·0	859·0	59·9	9·65	..	..
	988·0	598·0	60·5	9·86	..	..
	1183·0	743·0	62·8	9·72	..	..
	1524·0	947·0	62·1	9·29	..	..
	5129·0	3147·0	61·3 (over age)	9·60	5·4	38·7
Ashy Mauritius	1715·5	1280·0	74·6	16·09	..	..
	1688·0	1254·0	74·2	15·31	..	..
	1824·5	1347·0	73·8	15·31	..	..
	1452·0	1064·5	73·3	14·80	..	..
	6680·0	4945·5	74·0 (over age)	15·39	6·4	26·0

The extraction is calculated as follows :—

(1) In the case of Reora—

100 parts cane=61·3 parts juice=$\frac{61\cdot3\times9\cdot6}{100}$ parts sucrose=5·88 parts sucrose.

100 parts cane=38·7 parts bagasse=$\frac{38\cdot7\times5\cdot4}{100}$ parts sucrose=2·09 parts sucrose

100 parts cane=7·97 parts sucrose, of which 5·88 parts, or 73·8 per cent., were extracted in the juice. The extraction was 73·8 per cent., and the juice expressed per 100 cane 61·3.

(2) In the case of Ashy Mauritius—

100 parts cane=74·0 parts juice=$\frac{74\cdot0\times15\cdot39}{100}$ parts sucrose=11·39 parts sucrose.

100 parts cane=26·0 parts bagasse=$\frac{26\cdot0\times6\cdot4}{100}$ parts sucrose=1·66 parts sucrose.

100 parts of cane=13·05 parts of sugar of which 11·39 parts or 87·2 per cent. were extracted in the juice. The extraction was 87·2 per cent., and the juice expressed per 100 cane 74.

The results calculated in this manner are recorded in the following tables :—

1911-1912.

Variety.	Juice expressed per 100 of cane.	Sucrose in 100 parts of juice.	Bagasse per 100 parts of cane.	Sucrose per 100 parts of bagasse.	Sucrose extracted per 100 sucrose in cane.
Ashy Mauritius	71·2	15·58	28·8	6·5	86·0
Katara	70·0	12·30	30·0	4·7	86·0
Khari	67·4	13·11	33·6	4·5	85·7
Saretha	64·2	13·12	35·8	4·9	83·3
Sonabelli	65·5	14·26	34·5	5·8	82·6
Chin	63·5	14·19	36·5	5·5	81·9
Pansari of Ghazipur	67·4	11·41	33·6	5·7	80·9
Reori of Benares	64·2	11·76	35·8	5·3	80·3
Reora of Benares	68·0	13·96	32·0	7·8	79·7
Saranti of Partabgarh	65·0	11·41	35·0	5·4	79·6
Momcha of Basti	65·1	12·68	34·9	6·2	79·3
Mango of Shahganj	64·8	13·18	35·2	6·6	79·0
Mutna of Cawnpur	66·2	10·33	33·8	5·6	78·6
Dhaur of Azamgarh	65·1	13·07	34·9	6·9	78·0
Reora of Gorakhpur	65·0	14·21	35·0	8·1	76·5
Kewahi of Benares	61·9	11·85	38·1	5·9	76·4
Hemja of Gorakhpur	62·7	15·47	37·3	8·1	76·3
Charkhai of Azamgarh	64·4	10·67	35·6	6·1	76·3
Saranti of Basti	60·8	12·70	39·2	6·8	74·2
Kuswar	63·4	11·16	36·6	7·0	73·7

1912-1913.

Variety.	Juice expressed per 100 parts of cane mean of 4 determinations.	Sucrose per 100 parts of juice mean of 4 determinations.	Bagasse per 100 parts of cane mean of 4 determinations.	Sucrose per 100 parts of bagasse.	Sucrose extracted per 100 sucrose in cane.
Ashy Mauritius	74·0	15·39	26·0	6·5	87·2
Khari of Dumraon	65·0	10·12	35·0	3·7	83·5
Sonabelli of Dumraon . . .	64·5	11·38	35·5	4·5	82·1
Katara of Sultanpur	66·8	7·36	33·2	3·8	79·5
Saretha of Aligarh	58·7	12·70	41·3	4·7	79·3
Mutna of Cawnpur	61·3	8·81	38·6	4·3	76·4
Dhaur of Azamgarh . . .	60·6	11·21	39·4	5·8	74·8
Ramgol of Allahabad	59·8	11·24	40·2	5·7	74·6
Mango of Shahganj	61·1	10·59	38·9	5·8	74·2
Reora of Gorakhpur . . .	61·3	9·60	38·7	5·4	73·8
Kuswar of Partabgarh . . .	60·8	9·77	39·2	5·4	73·7
Pansari of Ghazipur	61·4	11·33	38·6	6·7	72·9
Reora of Benares	60·5	9·33	39·5	5·6	71·9
Hemja of Gorakhpur	60·0	9·44	40·0	5·7	71·3

An exceedingly high order of extraction was obtained, and at first sight it might be assumed, that such high values could not be given by mills in which the rollers are working vertically. If, however, the facts (1) that a very small amount of cane is crushed, and (2) that the rollers revolve very slowly are considered, there is no reason why these mills which are exceedingly easily adjusted, should not be efficient. The cost of crushing is an entirely different matter. The slow rate at which cane can be crushed, and the large amount of bullock power required,

makes the cost of crushing high. It is doubtful for single dry crushing if any type of mill will extract a larger proportion of sugar, but the cost of crushing can be probably lowered by the use of some other form of power, and the bullocks at present employed freed for other work connected with tillage operations.

Somers—Taylor (*loc. cit.*) has determined the fibre in the cane and bagasse of varieties grown at the Sabour Farm, using a similar type of mill. From these results the extraction can be calculated from the formula $1{\cdot}03 \left(\frac{m-f}{m(-1f)}\right)$ mentioned in the preceding pages. It is interesting to note that the values thus calculated are of the same order, and show the same variations between varieties, as those obtained by an entirely different method at Partabgarh and Shahjahanpur.

The milling property as expressed by the extraction is an important factor in determining the value of a cane, but it is one of several, and, because a cane gives a high extraction, it must not be assumed that it is suitable in all respects. In the seasons 1911-12 and 1912-13, the following varieties gave the highest extraction :—

Ashy Mauritius,
Katara (Sultanpur),
Kheri,
Saretha,
Sonabelli.

Only two of these, Ashy Mauritius and Saretha, are good field varieties in the Upper Doab. The good milling properties of the latter variety accounts doubtless, for some of its popularity in the gur-producing districts of the West. The other three varieties are somewhat difficult to grow and liable to the attacks of pests of various kinds. Reora of Benares, a very popular cane in the Eastern districts, in an average year, gives a rather low extraction ; but a good yield of cane and a good juice, and, although it does not stand out in any one particular respect, a combination of qualities makes it a desirable cane for those parts.

The figures given in the above table show, beyond reasonable doubt, that a very high order of extraction can be secured if the best type of 3 roller bullock mill is working properly. For single dry crushing it is doubtful if it could be exceeded by any type of mill. To secure this the strain on the bullocks is great throughout the crushing season, and the rate of crushing is slow.

Such a high efficiency cannot be maintained for any length of time by the cultivators with their light, and very often under-fed cattle. An examination of the bagasse from village mills makes it only too evident that efficiency has to be sacrificed, and the mill loosened, to enable the crushing to be done at all. The juice expressed per 100 of cane by the not / cultivators does, of course, reach anything like the high figure recorded in these pages. It varies greatly. This is the result not so often of bad cane or bad mills, but of insufficient power to use the mills at their full efficiency.

During the progress of the work at Partabgarh in 1913, records were kept of the amount of cane crushed daily from five mills running simultaneously, each mill with two pairs of bullocks working in shifts of two hours each. Typical results are given in the following table :—

Variety.	No. of mills.	No. of bullocks.	Time (hours).	Weight of cane crushed. (lbs.)	Weight of cane per mill per hour. (lbs.)	Weight of cane per mill per hour. (mds.)
Saretha	5	20	6	4,360	145·3	1·76
Chin	,,	,,	,,	4,448	148·2	1·77
Sarauti	,,	,,	7·5	5,424	144·3	1·75
Ashy Mauritius . . .	,,	,,	6	4,508	150·2	1·83
Sonabelli	,,	,,	8	5,336	133·4	1·62
Sarauti	,,	,,	9	5,480	121·8	1·48
AVERAGE .	..	..	..	..	..	1·70

Further tests were carried out in the season 1913-14 at Shahjahanpur to ascertain the amount of cane crushed, and the extraction obtained, in the 3 roller iron bullock mill used at Partabgarh with a variety widely grown in the Rohilkhand Division known as Dikchan. The cane was of average quality.

The results of two days' work with one mill are given in the following tables :—

3 roller iron bullock mill 8″ rollers.

Experiment I.

Time hours.	Weight of cane crushed. (lbs.)	Weight of juice. (lbs.)	Juice expressed per 100 cane.	Sucrose per 100 juice.	Bagasse per 100 cane.	Sucrose per 100 bagasse samples taken every hour.	Cane crushed per mill per hour. (Mds.)	Extraction.
6	1276·5 (15·5 mds).	856·5	67·1	15·57	32·9	7·1 7·1 7·3 7·3 7·2 7·8 7·9	2·58	81·1
					AVERAGE.	7·4		

Experiment II.

8·5	1740 (21·1 mds.)	1157·5	66·5	15·00	33·5	7·3 7·3 7·4 7·4 7·3 7·0 7·5	2·48	80·1
					AVERAGE.	7·3		

The test recorded in the preceding tables was carried out under experiment station conditions, with heavy bullocks and the best type of mill that could be procured. The mill was frequently adjusted and every effort made to secure the most favourable conditions. They are of interest as showing what is possible with United Provinces canes.

In order to obtain some indication of the possibilities of smaller types of iron mills in use in the neighbourhood, a mill with 6″ rollers was hired in the village of Deoria, and the owners were asked to bring it

to the farm with two pairs of their own bullocks, and to crush a "mata" of juice. The best mill in the village was not selected; one that appeared to be an average one was taken. The owners of the mill came to the farm with 3 somewhat light bullocks and a buffalo, and fixed up the mill. They were given 10 maunds of cane to crush and left to their own devices with the exception that care was taken to see that the juice was taken to the balance without loss, and weighed, and sampled as usual. The results of two days' work are given in the following tables :—

Smaller type of 3 roller iron bullock mill 6″ rollers.

Experiment I.

Time hours.	Weight of cane crushed. (lbs.)	Weight of juice. (lbs.)	Juice expressed per 100 cane.	Sucrose per 100 juice.	Bagasse per 100 cane.	Sucrose per 100 bagasse samples taken every hour.	Cane crushed per mill per hour. (Mds.)	Extraction.
						7·7 8·5 8·6 8·3 8·3 8·0		
5·5	823·0 (10 mds.)	489·5	59·4	16·11	40·6		1·81	74·2
				Average.		8·2		

Experiment II.

						7·7 7·7 7·7 7·9 7·9 7·5		
5·75	880·0 (10·7 mds.)	534·0	60·0	15·65	40·0		1·86	75·3
				Average		7·7		

The extraction obtained by the Deoria cultivators with their small 6 inch roller iron mill was good, though less than that obtained with the

heavier mill and bullocks of the Experiment Station. It is a reasonable supposition that, stimulated by their surroundings at the farm, the mill owners would give an extra turn or two to their adjustment, and that the extraction was therefore higher than obtained in every day practice. This experiment is of interest because it shows that even with the lighter mills a reasonable extraction can be obtained if the necessary power is available.

It may be mentioned that in these tests particular attention was paid to the sampling of the bagasse. Samples were collected from the mill at intervals of an hour in a box specially designed to prevent drying, and at once reduced to a fine and uniform state of sub-division in a bagasse sampler. The whole operation from the mill to the balance not taking more than 10 minutes. The results of the bagasse analysis as seen from the above table are in close agreement. The slightest variation in the bearing of the mill could be detected at once.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET

Bulletin No. 43 1914

Agricultural Research Institute, Pusa

A Note on the Effect of Heat on the Rinderpest Immune Bodies

BY

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Dieu et mon Droit

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1914

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A note on the effect of heat on the Rinderpest Immune Bodies.

RINDERPEST anti-serum, when protected from light and kept at a temperature under 90°F., maintains its original potency for long periods (two years).

Certain tests carried out by Lingard showed that serum kept in the plains of India, when exposed for a length of time to a shade temperature of over 90°F., deteriorated in potency.

Serum kept in the plains for six and a half months, during which the maximum shade temperature varied from 78°F. to 126°F., is said to have lost 40 to 66 per cent. of its protective value.

A sample of serum deposited in Madras for two months, during which the maximum shade temperature rose to 105·5°, apparently lost 55 per cent. of its potency.

Another sample of serum, kept for twenty-six months, in the plains and exposed to two hot seasons, when the maximum temperature rose to 108°F., was found to have deteriorated in value by 55 per cent.

The conclusion has, consequently, been arrived at that prolonged exposure to a shade temperature of over 90°F. is detrimental to Rinderpest anti-serum.

In field operations in the plains of India the serum is frequently exposed for short periods to a high temperature.

In order to ascertain if exposure to a moderately high temperature for several days or to high temperature for a short period had any detrimental effect on the serum the following tests were carried out. Another object of these experiments was to determine the effect of sterilisation on the potency of the serum.

The effect of keeping serum at 45°C. (113°F.) for seven days.

A quantity of serum (Brew 84) was kept at 45°C. for seven days after which its protective power was tested on hill cattle.

The original potency was fixed at a dose of 90 c. c. per 600 lbs. body weight for hill cattle.

Two bulls were injected with a quantity of serum at the rate of 90 c. c. per 600 lbs. body weight and at the same time received an inoculation of 0·5 c. c. fresh Rinderpest blood.

Bull No. 2078.—Inoculated with 22·20 c. c. serum heated for seven days at 45°C.+0·5 c. c. defibrinated V. B. from Bull No. 2073.

5th day	40·9°C.	
6th „	40·6°C.	
7th „	40·4°C.	
8th „	40·2°C.	
10th „	40·5°C.	Vesicles.
11th „	39·7°C.	Ulcers, diarrhœa.
12th „	38·6°C.	„ „
13th „	37·9°C.	Ulcers healing, diarrhœa.
14th „	38·2°C.	„ „ fæces soft.
15th „	39·2°C.	„ healed up.
24th „	Discontinued.	

Bull No. 2075.—Inoculated with 22·80 c. c. serum heated for seven days at 45°C.+0·5 c. c. defibrinated V. B. from Bull No. 2073.

9th day	40·5°C.	Vesicles.
10th „	40·0°C.	„ ulcers, diarrhœa.
11th „	38·5°C.	Ulcers, diarrhœa.
12th „	36·1°C.	„ „
13th „	Died.	

The following was the original test of this Brew of serum No. 84.

Serum Testing.

Bull No. 1032. Inoculated with 10·20 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 1005. (36 c. c. per 600 lbs. body weight.)

4th day	40·1°C.	
5th ,, ...	40·8°C.	
6th ,, ...	41·1°C.	
7th ,, ...	41·1°C.	
8th ,, ...	41·0°C.	Vesicles.
9th ,, ...	40·7°C.	Vesicles and ulcers.
10th ,, ...	39·8°C.	Ulcers healing.
11th ,, ...	39·0°C.	,, ,,
12th ,, ...	Died	

Bull No. 1031.—Inoculated with 10·32 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 1005. (36 c. c. per 600 lbs. body weight.)

4th day	40·5°C.	
5th ,, ...	40·7°C.	
6th ,, ...	40·6°C.	Fæces soft.
7th ,, ...	40·5°C.	Vesicles, fæces soft.
8th ,, ...	40·5°C.	Ulcers, diarrhœa.
9th ,, ...	40·8°C.	,, ,,
10th ,, ...	37·5°C.	Ulcers healing.
11th ,, ...	37·3°C.	,, ,, diarrhœa.
12th ,, ...	36·0°C.	,, ,, ,,
13th ,, ...	Died.	

Bull No. 1033.—Inoculated with 20·52 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 1005. (54 c. c. per 600 lbs. body weight.)

6th and 7th day . .	41·0°C.
23rd day	Discontinued.

Bull No. 1034.—Inoculated with 22·56 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 1005. (54 c. c. per 600 lbs. body weight.)

4th day	40·1°C.	
5th ,,	40·4°C.	
6th and 7th day	40·6°C.	
8th day	40·5°C.	
9th ,,	40·6°C.	
10th ,,	39·7°C.	Vesicles.
11th ,,	39·8°C.	,, and ulcers.
12th ,,	39·0°C.	Ulcers.
13th ,,	39·8°C.	,, healing.
14th ,,	39·0°C.	Ulcers healed up.
23rd ,,	Discontinued.	

Bull No. 1037.—Inoculated with 31·50 c. c.+0·5 c. c. defibrinated V. B. from Bull No. 1005. (108 c. c. per 600 lbs. body weight.)

4th day	40·6°C.	
5th ,,	41·5°C.	
6th ,,	41·3°C.	
7th ,,	41·2°C.	Vesicles.
8th ,,	41·2°C.	Ulcers.
9th ,,	40·8°C.	,,
10th ,,	40·6°C.	,, healing.
11th ,,	40·0°C.	,, ,, diarrhœa.
12th ,,	39·6°C.	,, ,, ,,
13th ,,	39·8°C.	,, ,, ,,
14th ,,	39·8°C.	,, healed up.
23rd ,,	Discontinued.	

Bull No. 1036.—Inoculated with 31·86 c. c. serum + 0·5 c. c. defibrinated V. B. from Bull No. 1005. (108 c. c. per 600 lbs. body weight.)

4th-6th day	40·5°C.
7th day	40·0°C.
23rd ,,	Discontinued.

The result shows that serum heated to 45°C. (113° F.) for seven days does not lose any of its protective value.

The effect of heating serum to 55°C.(131°F.) for one hour.

After heating, the serum was tested on two hill bulls in the usual methods. The dose of serum used was at the rate of 90 c. c. per 600 lbs. body weight.

Bull No. 1098.—Inoculated with 25·60 c. c. serum heated for 1 hour at 55°C.+0·5 c. c. defibrinated V. B. from Bull No. 1021. (90 c. c. per 600 lbs. body weight.)

6th day	40·2°C.	
7th ,,	40·2°C.	
8th ,,	40·5°C.	
9th ,,	41·4°C.	
10th ,,	40·3°C.	Vesicles.
11th ,,	39·5°C.	Ulcers.
12th ,,	39·6°C.	,, healing.
13th ,,	39·4°C.	,, healed up.
17th ,,	Discontinued.	

Bull No. 1105.—Inoculated with 25·60 c. c. serum heated for 1 hour at 55°C.+0·5 c. c. defibrinated V. B. from Bull No. 1021. (90 c. c. per 600 lbs. body weight.)

6th day	40·4°C.	
8th ,,	40·0°C.	
10th ,,	39·5°C.	Vesicles.
11th ,,	39·4°C.	Ulcers.
12th ,,	39·7°C.	,, healing.
13th ,,	39·4°C.	,, healed up.
17th ,,	Discontinued.	

The following was the original test of this Brew of serum No. 82 :—

Serum Testing.

Bull No. 577.—Inoculated with 10·62 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 531. (36 c. c. per 600 lbs. body weight.)

5th day	40·8°C.	
6th ,,	41·0°C.	
7th ,,	41·3°C.	
8th ,,	40·6°C.	
9th ,,	40·8°C.	Vesicles.
10th ,,	40·1°C.	Ulcers.
11th ,,	40·5°C.	Ulcers healing, diarrhœa.
12th ,,	36·5°C.	,, ,, ,,
13th ,,	Died.	

Bull No. 1034.—Inoculated with 22·56 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 1005. (54 c. c. per 600 lbs. body weight.)

4th day	40·1°C.	
5th ,, ...	40·4°C.	
6th and 7th day . .	40·6°C.	
8th day	40·5°C.	
9th ,, ...	40·6°C.	
10th ,, ...	39·7°C.	Vesicles.
11th ,, ...	39·8°C.	,, and ulcers.
12th ,, ...	39·0°C.	Ulcers.
13th ,, ...	39·8°C.	,, healing.
14th ,, ...	39·0°C.	Ulcers healed up.
23rd ,, ...	Discontinued.	

Bull No. 1037.—Inoculated with 31·50 c. c.+0·5 c. c. defibrinated V. B. from Bull No. 1005. (108 c. c. per 600 lbs. body weight.)

4th day	40·6°C.	
5th ,, ...	41·5°C.	
6th ,, ...	41·3°C.	
7th ,, ...	41·2°C.	Vesicles.
8th ,, ...	41·2°C.	Ulcers.
9th ,, ...	40·8°C.	,,
10th ,, ...	40·6°C.	,, healing.
11th ,, ...	40·0°C.	,, ,, diarrhœa.
12th ,, ...	39·6°C.	,, ,, ,,
13th ,, ...	39·8°C.	,, ,, ,,
14th ,, ...	39·8°C.	,, healed up.
23rd ,, ...	Discontinued.	

Bull No. 1036.—Inoculated with 31·86 c. c. serum + 0·5 c. c. defibrinated V. B. from Bull No. 1005. (108 c. c. per 600 lbs. body weight.)

4th-6th day . . .	40·5°C.
7th day	40·0°C.
23rd ,, ...	Discontinued.

The result shows that serum heated to 45°C. (113° F.) for seven days does not lose any of its protective value.

The effect of heating serum to 55°C.(131°F.) for one hour.

After heating, the serum was tested on two hill bulls in the usual methods. The dose of serum used was at the rate of 90 c. c. per 600 lbs. body weight.

Bull No. 1098.—Inoculated with 25·60 c. c. serum heated for 1 hour at 55°C.+0·5 c. c. defibrinated V. B. from Bull No. 1021. (90 c. c. per 600 lbs. body weight.)

6th day	40·2°C.		
7th ,,	40·2°C.		
8th ,,	40·5°C.		
9th ,,	41·4°C.		
10th ,,	40·3°C.	Vesicles.	
11th ,,	39·5°C.	Ulcers.	
12th ,,	39·6°C.	,,	healing.
13th ,,	39·4°C.	,,	healed up.
17th ,,	Discontinued.		

Bull No. 1105.—Inoculated with 25·60 c. c. serum heated for 1 hour at 55°C.+0·5 c. c. defibrinated V. B. from Bull No. 1021. (90 c. c. per 600 lbs. body weight.)

6th day	40·4°C.		
8th ,,	40·0°C.		
10th ,,	39·5°C.	Vesicles.	
11th ,,	39·4°C.	Ulcers.	
12th ,,	39·7°C.	,,	healing.
13th ,,	39·4°C.	,,	healed up.
17th ,,	Discontinued.		

The following was the original test of this Brew of serum No. 82 :—

Serum Testing.

Bull No. 577.—Inoculated with 10·62 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 531. (36 c. c. per 600 lbs. body weight.)

5th day	40·8°C.			
6th ,,	41·0°C.			
7th ,,	41·3°C.			
8th ,,	40·6°C.			
9th ,,	40·8°C.	Vesicles.		
10th ,,	40·1°C.	Ulcers.		
11th ,,	40·5°C.	Ulcers healing, diarrhœa.		
12th ,,	36·5°C.	,,	,,	,,
13th ,,	Died.			

Bull No. 578.—Inoculated with 12 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 531. (36 c. c. per 600 lbs. body weight.)

4th day	40·0°C.	
5th ,, ...	40·6°C.	
6th ,, ...	40·9°C.	
7th ,, ...	40·6°C.	
8th ,, ...	40·7°C.	Vesicles.
9th ,, ...	40·4°C.	Ulcers.
10th ,, ...	38·6°C.	,, diarrhœa.
11th ,, ...	Died.	

Bull No. 580.—Inoculated with 24·84 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 531. (54 c. c. per 600 lbs. body weight.)

8th and 10th day . .	40·0°C.
17th day	Discontinued.

Bull No. 582.—Inoculated with 24·84 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 531. (54 c. c. per 600 lbs. body weight.)

5th day	40·5°C.
6th and 7th day . .	41·2°C.
8th day . . .	41·0°C.
9th ,, ...	40·5°C.
17th ,, ...	Discontinued.

Bull No. 579.—Inoculated with 38·52 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 531. (108 c. c. per 600 lbs. body weight.)

5th and 7th day . .	40·5°C.
8th day	40·7°C.
9th ,, ...	40·1°C.
17th ,, ...	Discontinued.

Bull No. 581.—Inoculated with 39·60 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 531. (108 c. c. per 600 lbs. body weight.)

No lesions or temperature reaction.

17th day	Discontinued.

Serum heated to 55°C. (131°F.) for one hour does not lose any of its potency.

The effect of heating serum to 60°C. (140°F.) for 1 hour.

The heated serum was tested on four hill bulls. The dose of serum used was at the rate of 45 c. c. and 90 c. c. per 600 lbs. body weight.

Bull No. 78.—Inoculated with 13·05 c. c. serum heated for 1 hour at 60°C.+0·5 c. c. defibrinated V. B. from Bull No. 79. (45 c. c. per 600 lbs. body weight.)

8th day	40·4°C.	
9th ,, ...	40·0°C.	Vesicles.
10th ,, ...	39·5°C.	,,
11th ,, ...	39·5°C.	Ulcers, diarrhœa.
12th ,, ...	39·0°C.	,, healing, slight diarrhœa.
13th ,, ...	38·1°C.	,, healed up.
18th ,, ...	Discontinued.	

Bull No. 77.—Inoculated with 13·80 c. c. serum heated for 1 hour at 60°C.+0·5 c. c. defibrinated V. B. from Bull No. 79. (45 c. c. per 600 lbs. body weight.)

5th day	40·0°C.	
6th ,, ...	40·0°C.	
7th ,, ...	40·4°C.	
8th ,, ...	40·4°C.	
9th ,, ...	40·1°C.	Vesicles.
10th ,, ...	39·2°C.	,, ulcers, slight diarrhœa.
11th ,, ...	39·3°C.	Ulcers healing.
12th ,, ...	38·4°C.	,, healed up.
18th ,, ...	Discontinued.	

Bull No. 61.—Inoculated with 27·15 c. c. serum heated for 1 hour at 60°C.+0·5 c. c. defibrinated V. B. from Bull No. 34. (90 c. c. per 600 lbs. body weight.)

6th day	40·5°C.
7th ,, ...	40·0°C.
17th ,, ...	Discontinued.

Bull No. 72.—Inoculated with 28·50 c. c. serum heated for 1 hour at 60°C.+0·5 c. c. defibrinated V. B. from Bull No. 34. (90 c. c. per 600 lbs. body weight.)

6th day	40·0°C.
7th ,, ...	40·5°C.
17th ,, ...	Discontinued.

The following was the original test of this Brew of serum No. 86 :—

Serum Testing.

Bull No. 1.—Inoculated with 12·66 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 4. (36 c. c. per 600 lbs. body weight.)

6th day	40·0°C.	
7th „	40·1°C.	
9th and 10th day . .	40·0°C.	
21st day	Discontinued.	

Bull No. 5.—Inoculated with 12·66 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 4. (36 c. c. per 600 lbs. body weight).

4th day	40·3°C.	
5th „	40·7°C.	
6th „	41·0°C.	
7th „	40·9°C.	
8th „	40·6°C.	
9th „	40·4°C.	Vesicles.
10th „	40·5°C.	„ diarrhœa.
11th „	40·0°C.	„ ulcers.
12th „	39·0°C.	Ulcers healing.
13th „	38·9°C.	„ „ diarrhœa.
14th „	38·5°C.	„ „ „
15th „	38·2°C.	„ „ „
16th „	37·6°C.	„ „ „
17th „	38·8°C.	„ „ „
21st „	Discontinued.	

Bull No. 6.—Inoculated with 22·08 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 4. (54 c. c. per 600 lbs. body weight.)

7th day	40·1°C.	
11th „	39·0°C.	Vesicles.
12th „	39·6°C.	Ulcers.
13th „	39·1°C.	„ healing.
14th „	40·0°C.	„ healed up.
21st „	Discontinued.	

Bull No. 15.—Inoculated with 25·56 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 4. (54 c. c. per 600 lbs. body weight.)

7th-10th day . . .	40·0°C.
21st day	Discontinued.

Bull No. 19.—Inoculated with 37·98 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 4. (108 c. c. per 600 lbs. body weight.)

9th-11th day . . .	40·0°C.
21st day	Discontinued.

Bull No. 24.—Inoculated with 38·70 c. c. serum+0·5 c. c. defibrinated V. B. from Bull No. 4. (108 c. c. per 600 lbs. body weight.)

6th-7th day . . .	40·0°C.
8th day	40·4°C.
9th „	40·3°C.
21st „	Discontinued.

A serum heated to 60°C. (140°F.) for one hour retains its original potency.

Conclusions.

The results of these tests are in support of the conclusion that Rinderpest anti-serum does not become altered in potency by a short exposure to a high temperature ; also that the sterilisation of this serum can be accomplished without any detriment to the value of the serum.

The results are also of a further interest inasmuch as they show that the action of the Rinderpest anti-serum is not dependent on a complement contained in itself.

The experiments of Pfeiffer demonstrated that a serum was inactivated by heating to 55°C. and that inactivated serum did not kill or dissolve the bacilli against which it was prepared. It was necessary to add fresh complement obtained from the serum of a healthy animal in order to restore the destructive action.

Immune bodies are not altered by exposure to a temperature of 60-65°C. for a period of an hour whereas the complement of serum is destroyed by heating to 55°C. for half an hour.

The Rinderpest serum evidently obtains a suitable complement in the body of injected cattle.

The experiments of Todd and White[1] on the hæmolysin of the ox showed that though a suitable complement for the hæmolytic immune serum could not be demonstrated in vitro, from the serum it was actually present in the animal body.

They found that the isolysin present in the serum of the immune cattle did not act with the complement free in the blood of these cattle but appeared to require a foreign complement. This is not in accordance with what was found by Ehrlich and Morgenroth[2] in their investigation with isolytic goat sera. In the case of the goat the injection of the animal with the corpuscles of another individual gives rise to an isolysin which acting in conjunction with the complement normally present in the serum of the goat causes the solution of the corpuscles.

Todd and White, however, were able to demonstrate that although the isolysin did not act with the complement present in ox serum, a suitable complement does exist elsewhere in the body.

Fresh immune serum which showed no reaction on ox corpuscles in vitro unless foreign complement were added was injected into a bull.

One litre of the serum was injected intravenously and a few hours after the injection the urine was very darkly hæmoglobin stained, showing that a suitable complement had been forthcoming.

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[1] Todd and White. On the Hæmolytic Immune Isolysins of the Ox and their relation to the question of Individuality and Blood Relationship. *Journal of Hygiene*, Vol. X, 1910, pp. 185—195.

[2] Ehrlich and Morgenroth. Studies on Hæmolysis.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

Bulletin No. 44 1915

Agricultural Research Institute, Pusa

How to improve Silk-Reeling in Bengal

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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Superintendent Government Printing, India, Calcutta

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PREFACE.

THIS Bulletin has been prepared by Mr. M. N. De, Sericultural Assistant at Pusa, and contains practical hints on improved methods which are recommended to be used for reeling mulberry silk in Bengal and other silk producing districts. It has been found that, by the provision of two small pulleys to the ordinary Bengal type of reeling machine, superior thread can be obtained, the cost of the extra apparatus is merely nominal (five or six annas per machine), whilst the suitability of the machine for cottage workers is maintained.

By attention to such simple points as the stifling and storage of cocoons and the temperature and quality of the water used in the reeling pans, great improvements can be effected in most silk centres in Bengal and other districts. It is hoped that the information given in this Bulletin may be found of practical use to the Silk Trade.

PUSA;
20th July 1914.

T. BAINBRIGGE FLETCHER,
Imperial Entomologist.

B

HOW TO IMPROVE SILK-REELING IN BENGAL.

Introduction.

Sericulture involves three operations :—(1) The growing of mulberry trees, (2) The rearing of the worms, and (3) The reeling of the cocoons. From each mulberry cocoon one uniform continuous single thread about 500 to 2,000 feet in length can be obtained. The process of unwinding the thread is called reeling. Raw silk or reeled silk is prepared by boiling the cocoons in hot water and drawing filaments of 6 to 20 cocoons into one thread on a reel.

The principal causes of the decline of the silk industry are (1) Diseased and weak worms which spin small and bad cocoons, (2) Foreign competition, (3) Defective system of reeling, and (4) Want of organization.

(1) The nurseries set up by the Government of Bengal and by private enterprise in Murshidabad, Rajshahi and Maldah cannot produce more than Rs. 15,000 worth of disease-free eggs in a year whereas the rearers of Bengal require more than a lakh of rupees worth of eggs per year. In countries where sericulture has made great advancement only licensed high class breeders are allowed to sell eggs or Government take up the monopoly of supplying eggs, but in India there are no restrictions and any rearer can sell his produce as seed cocoons, often with the inevitable result of spreading diseases and causing many failures. The multivoltine silkworm races of India yield silk which is inferior both in quality and outturn to that of the univoltine races of China, Japan, Italy and France.

(2) With the opening of new ports to foreigners raw silk began to be exported to Europe in large quantities from China and Japan and Bengal silk came into disfavour. The Indian reelers do not know the

demands of the foreign markets and they are satisfied with preparing the same old coarse threads on their old-fashioned reeling machines. The other silk producing countries of the world prepare threads suited to the requirements of the consumers, but in India the illiterate reelers have no such information to guide them.

(3) Indian silk contains more gum and colouring matter than the foreign univoltine silk and the filament of each cocoon being shorter (about 1,000 feet) in length the ends have to be attached more often at the time of reeling which causes non-uniformity in the thread; in the Indian cocoon when the filament is nearly exhausted the parchment-like layer is drawn out of the reeling water and causes unevenness in the thread; but in the univoltine cocoon whose filament is about 1,500 feet to 2,000 feet in length there is less chance of such non-uniformity. (*a*) The raw or green cocoons are stifled and dried in the sun and thus lustre and strength of the thread are lost to some extent. (*b*) The cocoons are boiled and reeled in the same pan so that it is very difficult to keep a uniform temperature in the reeling pan. (*c*) Too many cocoons are boiled at a time and the boiled cocoons are kept in the reeling pan for a long time and thus the weight, lustre and elasticity of the filaments are lost. (*d*) While joining the filaments the Bengal reelers keep very long ends. (*e*) The water used for reeling is very often hard and unsuitable for reeling. (*f*) The hole, through which the filaments of a single thread are passed, is very big and forms what are called knobs, fouls and knifs. (*g*) They give only 2 or 3 croisseurs or twists instead of 200—350. (*h*) Threads are not tied whilst being reeled, if broken. (*i*) The cocoons are handled too roughly in the boiling pan. (*j*) Any number of cocoons is reeled at a time according to the convenience of the reeler without caring for the denier (uniform thickness). (*k*) The reel is made to revolve according to the convenience of the winder. (*l*) Dust and smoke are allowed to fall on the reeled thread. (*m*) The raw silk is not re-reeled.

(4) Want of organization is one of the worst features in all Indian industries. The reelers do not know where to sell their goods at an advantage. They are almost always compelled to take advances from the Marwari money-lenders and sell the thread at a cheap rate; these middlemen generally absorb the lion's share of the profit. The reelers do not know that many foreign merchants are anxious to buy Indian silk in small or large quantities. Another drawback which the Indian raw silk trade suffers from is the want of a Silk Conditioning House in Calcutta or Bombay through which all the silk for export should pass.

As silk is very hygroscopic it is customary to determine the quantity of moisture in each lot at the time of sale in a Government Conditioning House. The advantage to the buyer of "conditioned silk" is that he is sure to get the full weight of silk without paying for moisture. The buyer is protected against fraud by this procedure and only good silk is exported from the country. All silk producing and consuming countries have got at least one Conditioning House managed by Government officials.

Special use of Indian silk.—The filaments of multivoltine cocoons are as good structurally as the univoltine ones. Bengal silk, if properly reeled, is suited for a few special purposes such as the making of black silk hats and for sewing purposes, and for these this silk is exclusively used. The European manufacturers have conceived a strong prejudice against Indian silk and it is our duty to remove it by exporting the best silk only.

By comparing the value of Indian silk and univoltine silk it may be ascertained to what condition Bengal silk has fallen. The value of univoltine silk in England is about 19 shillings per pound while that of Indian silk is from 8 shillings to 12*s*. 6*d*. per pound. It is not a fact that the Indian reelers cannot reel better thread but they aim at quantity rather than quality; they do not care to exploit new markets but stick to the old market. As long as the Indian millowners and weavers are anxious to get cheap raw silk there is very little hope for the amelioration of the condition of Bengal raw silk unless the producers try to sell their best raw silk to a foreign market.

By the provision of two extra small aluminium, glass or wooden wheels or pulleys in the Bengal system of reeling machine we have managed to give about 200—350 twists (*vide* illustration of the reeling machine, Plate II, page 10). In this method the simple country appliance for reeling has been greatly improved and yet its suitability for cottage workers maintained.

Foreign trade: *Exports:*—In 1772 about 180,000 lbs. of wound (raw) silk was exported to England from India; in 1785, 324,307 lbs.; in 1795, 380,352 lbs.; but 20 years later Bengal supplied 736,081 lbs. (Millburn's *Rise and Progress of the Silk Trade*). In 1805 the total exports were 835,904 lbs.; in 1825 they came to 919,436 lbs.; in 1835 about 727,535 lbs.; in 1867-68 about 2,226,201 lbs. valued at Rs. 1,55,32,290 (vide *Review of the Trade of India* by J. E. O'Conor). In 1877-78 the total exports from India were 1,512,819 lbs. valued at

Rs. 70,35,493; in 1887-88 about Rs. 48,08,000 worth of silk was exported to foreign countries; in 1892-93 about Rs. 61,75,000; in 1900-01, 1,604,275 lbs. valued at Rs. 51,22,057; in 1908-09 about 1,833,644 lbs. valued at Rs. 54,05,077; in 1909-10 about 1,207,561 lbs. valued at Rs. 50,75,739; in 1910-11, 1,847,401 lbs. valued at Rs. 50,55,287; in 1911-12, 359,555 lbs. raw silk valued at £208,669 and £686,915 worth of waste silk; and in 1912-13, 369,857 lbs. raw silk valued at £199,458 and £32,643 worth of silk waste were exported from India (vide *Annual Statement of the Sea-Borne Trade and Navigation of British India*).

The value of the exports has in recent years been steadily decreasing. Although the quantity of silk exported has not diminished very materially, the value of the export has declined to a third of what it was. In Europe the utilization of waste silk began to be understood from the year 1857 and consequently the exports of India changed their character. The returns rapidly manifested a decline in value, due largely to the increased quantity of export of waste silk and cocoons in place of the reeled silk.

Imports:—In 1876-77 the import of silk in India was valued at 58½ lakhs of rupees; in 1881-82, Rs.135 lakhs; in 1900-01, Rs. 1,66,58,108; in 1904-05, Rs. 2,11,81,502; in 1907-08, Rs. 3,00,00,000; the total value of silk, raw and manufactured, in 1908-09 is £2,200,181, in 1909-10 it is £2,162,597, in 1910-11 is £2,411,469, in 1911-12 is £2,475,556 and in 1912-13 is £3,187,193 (vide *Annual Statement of the Sea-Borne Trade and Navigation of British India*). These show a remarkable expansion. Bombay is the chief distributing centre; raw silk from China and Japan and spun silk from Europe are imported here and are carried through the Presidency of Bombay to the Punjab and even to the United Provinces. The Punjab may be called the great consuming province and Bengal the great producing province. Raw silk from Bengal is carried to Nagpur, Poona, Amritsar, Madras, Benares and to other centres of weaving. It is curious that in Bombay which has to depend upon raw material from outside, the silk manufacturing industry has taken comparatively large and active proportions, while in Bengal, the very centre of Indian silk production, there is only one big silk weaving mill to be found. The Bombay mills manufacture in considerable quantity for the Burmese market which is much closer to Bengal and there is also a large market in the United Provinces for the outturn of

PLATE I

REELING OR UNWINDING THREAD FROM MULBERRY COCOONS.

silk mills; but Bengal is content to produce in annually diminishing quantities for an unprofitable export market and confines its manufactures to a few *corahs* and other similar goods made by hand. Want of enterprise and manufacturing skill is the root cause of the decline of the silk industry here. It is indeed melancholy to record the continued decadence of the Indian silk industry as far at any rate as the production of reeled silk is concerned. The manufacture of silk keeps up steadily but a considerable proportion of the raw material required for manufacture is imported from China, Japan and Europe.

According to Mr. Natalis Ronds of Lyons, the greatest authority on Sericultural Statistics, India produces about 1,200,000 seers of silk and consumes about 1,320,000 seers of silk per year.

The Present Method of Reeling in Bengal.

The green or raw cocoons are stifled and dried in the sun for about 3 or 4 days and the dry cocoons are steamed for about 20 to 30 minutes to make the filaments of the cocoons loose and the steamed cocoons are boiled with water in the reeling pan for 2 or 3 minutes and are roughly handled by means of a brush. Then the free filaments of the cocoons are caught by a brush. Filaments from 30 to 50 cocoons (which go to make one single thread) are passed through a big hole of an iron plate and then through an iron hook and guider to the reel; filaments from another lot of 30 to 50 cocoons are passed through another big hole of the iron plate and hook and the thread is then crossed once or twice with the above thread and then it is passed through the guider to the reel. The reel is now turned by a winder and the reeler goes on adding new ends of 4 or 5 cocoons when some of the filaments from a thread are exhausted or broken. Sometimes when one thread is broken they do not tie at all but go on reeling, often putting the broken end on the thread already reeled; some tie no doubt but leave a big knot which makes the thread uneven. Then the skeins are prepared and the silk is ready for the market.

What should be done.

1. *The stifling of cocoons.*—Stifling is a process by which the pupæ are killed inside the cocoons and the moths are prevented from coming out. If the moths are allowed to come out the fine continuous single thread cannot be obtained and the cocoons become waste. Hence it is essential that they should be stifled. There are three conditions for stifling:—(*a*) That the filaments of the cocoons should not be spoiled, (*b*)

that stifling should be done as quickly as possible, and (*c*) that it should be economical. There are three methods of stifling, (1) by natural heat, *i.e.* by exposing the cocoons in the sun, (2) by chemicals, and (3) by heat or steam.

(1) Ordinary breeders can stifle the cocoons on a small scale by exposing them in the sun for about 2 or 3 days. In a big factory this process is quite impracticable as when dealing with large quantities it takes a long time to kill the pupæ or the moths. (2) The raw cocoons are exposed to carbon bisulphide in a sealed box or vessel. The gas soon stifles the pupæ or the moths; (carbon bisulphide gas is poisonous for human beings and being an explosive its use should be restricted). (3) There are three methods of stifling by artificial heat, (*a*) by applying direct fire, (*b*) by hot air, and (*c*) by steam.

(*a*) The use of this method is dangerous as cocoons are liable to be spoiled for there is a chance of their taking fire. (*b*) Stifling by hot air is the best. In this method the air can be heated in two ways, (*i*) by steam, (*ii*) by fire; if done carefully there is no difference between the two, but the steam system is preferable. (*c*) This process may be undertaken in a wooden box in which 2 or 3 perforated steam pipes are put in. At the time of stifling, the cocoons are placed inside the box which is then tightly closed so that no steam can escape from the box when the pipes are open. The cocoons are stifled in 8 or 10 minutes after the steam pipes are opened. The quality of the cocoons stifled by this method turns bad as dust and other impurities fall on the wet steamed cocoons and adhere to them. The most simple method of stifling cocoons on a small scale is as follows:—The cocoons should be placed in a basket over a boiling pan of water; the cocoons should be covered with a blanket or a gunny bag. The steam from the pan will completely stifle them in 15 or 20 minutes.

2. *Drying of Cocoons.*—Drying is done to store the cocoons for a long time. The quality of the thread becomes a little better by drying, for the dry cocoons do not produce as many knobs as the fresh or raw cocoons. The cocoons can be dried by exposing them in the sun for 4 or 5 days or by applying artificial heat. The quality of thread produced by the latter method is better. It takes about 12 hours to dry the cocoons completely if they are kept at a temperature of about 140°-200° F. It is important to dry the cocoons perfectly well. Fungi grow on the cocoons and spoil them if the drying is incomplete. The cocoons keep a good colour if they are reduced to about 33 per cent. of their original

weight. The drying is determined (1) by feeling, (2) by weight, and (3) by judging the time and temperature to which the cocoons are exposed. Over-dried cocoons turn brown and there is difficulty in unwinding the filaments from them. The denier, colour and lustre of full-dried cocoons are the best.

The best and the easiest way to stifle and dry the cocoons on a small scale is as follows:—The cocoons to be stifled and dried should be kept on trays the bottom of which is of iron wire gauze with small meshes and the trays are kept in a wooden box the bottom of which is of thick iron plate. There should be an arrangement to keep about 20 such trays within the box in two rows, the distance of each tray being about 5 inches. On the iron plate a layer of sand of about 2″ in depth is kept; the box should stand on 4 iron legs at a height of about 4 feet from the ground. Now if the lid is covered and heat is applied on the iron plate the sand in contact with it will be heated and the hot air will stifle and dry the cocoons in about 12 hours. The heat will not be uniformly distributed in all the trays; so that it is advisable to change the position of the trays after every half-an-hour or the cocoons will not be dried together. On the top of the box in the four corners there should be 4 small holes for the exit of vapour from the cocoons and the holes can be opened or closed at will. The villagers can easily stifle and dry their cocoons in such a box.

Method of storing Cocoons.—Dry cocoons should be stored in a dry well ventilated room in baskets or on trays over a bamboo framework. But if these are to be preserved for about a year they should be stored in wax cloth bags or tin boxes. They should also be protected from the attacks of insects and fungi. Dry cocoons can be stored in good condition for about a year.

Reeling.

Implements for reeling.—The following articles are necessary for reeling:—(1) Boiling pan in which cocoons are boiled for reeling, (2) Reeling pan in which boiled cocoons are kept for reeling, (3) Brush or broom for picking up the true filaments of cocoons, (4) Reel upon which the reeled thread is wound, (5) Porcelain Buttons (Agates) with very fine holes in the centre through which 5 or 6 filaments are passed, (6) Pulleys and Hooks for passing the thread easily to the reel, (7) Perforated bronze spoon for transferring the cocoons from the boiling to the reeling pan and *vice versâ*, (8) Guider for winding the thread on the reel uniformly, (9) Small vessels for keeping cold water and for preserving

unreelable parts of the cocoons and dead pupæ, (10) Water, (11) Fire or steam, (12) Power, either hand or machine.

Steaming the cocoons.—To make the filaments of the cocoons loose, the dry cocoons should be put into a basket over a boiling pan of water for about 25 or 30 minutes after covering the cocoons with a blanket or a gunny bag. This method should be adopted if small quantities of cocoons are to be steamed; in big filatures a separate room is constructed for it. Steaming is not necessary during the rains when the air is surcharged with excess of vapour and the filaments of the cocoons absorb the moisture and thus naturally turn loose. In a humid climate the process can be omitted.

Boiling of cocoons.—The filament has gummy matter outside and this attaches itself to the layer of cocoon in contact with it; to separate it, boiling in water is essential. The temperature of the water depends upon the quality and degree of dryness of the cocoons, *i.e.* raw cocoons of good quality require 165°-172° F., half-dried cocoons 200°-204° F., full-dried cocoons about 200°-208° F. and over-dried cocoons require 212° F. Cocoons of inferior quality should be boiled at 212° F. for a long time and multivoltine (thin) cocoons require less time than univoltine (thick) cocoons.

First the water is boiled to the required temperature; the cocoons are placed on the boiling pan and they are quickly turned with the bronze spoon smoothly and uniformly in such a way that all the cocoons are well soaked with hot water; otherwise the boiling will be non-uniform. The quantity of cocoons to be put on the pan at a time depends upon the capacity of the pan and the skill of the workman. An earthen pan whose diameter is about 1 foot is convenient. It is economical to fill the entire surface of the boiling water with cocoons in one layer and not one upon another. Heat should be applied uniformly on all sides. For boiling multivoltine cocoons a pan whose diameter is about 18 inches is convenient.

When the cocoons are silky to the touch and when the ends of the cocoons turn grey it is usually inferred they are well boiled; but this inference does not hold good in all cases. In yellow or bad white cocoons it is difficult to distinguish the colour when properly boiled. The time for boiling fresh thick cocoons is about 3 minutes while fresh thin cocoons require 2 minutes. Stifled compact cocoons require 5 minutes while stifled thin cocoons require 4 minutes; thick half-dried cocoons require 6 minutes while thin half-dried cocoons require 3 minutes. Full-

dried compact cocoons require 10 minutes while full-dried thin cocoons require 6 minutes. There cannot however be any hard and fast rule for boiling.

Disadvantages of over-boiled and under-boiled cocoons.—From under-boiled cocoons the filaments are often broken as the gummy matter still adheres, but the quantity of silk is greater. From over-boiled cocoons knobs come out of the filaments which spoil the quantity as well as the quality of the thread and produce much waste.

Searching for the true filaments.—After boiling is done the true filaments of the cocoons should be got hold of quickly. An unskilled reeler produces much waste in searching for these and spoils the quantity of the raw silk by roughly handling the filaments and turning the true filaments into waste silk so that the first and the best part of the cocoons is turned to waste. The cocoons are invariably turned into over-boiled ones. As soon as the cocoons are boiled they are removed to the reeling pan where the temperature of the water is low so that they will not be over-boiled. The filaments of the boiled cocoons should be got hold of smoothly by means of the handle of the bronze spoon; the filaments are brought to the reeling pan by catching them with the left hand and preventing the cocoons from unwinding by holding them with the spoon; then the true and uniform filaments are found out. In the course of reeling many filaments are broken before the cocoons are exhausted; these cocoons are boiled again for a few minutes and the brush is now smoothly and gently used over them to catch the true ends. If a large number of cocoons is boiled at a time it is better to keep some of them aside near the reeler, for if they are allowed to float on the reeling water for a long time the sericin is dissolved and there is loss both in outturn and quality.

Temperature of water in the reeling pan.—For all kinds of cocoons the standard temperature is 160°-150°F.; if the temperature is higher the sericin of the filaments is dissolved, many knobs from them come out, elasticity and tensile strength are lost and many splits come out. If the temperature is low, the filaments often break and there is much difficulty in reeling.

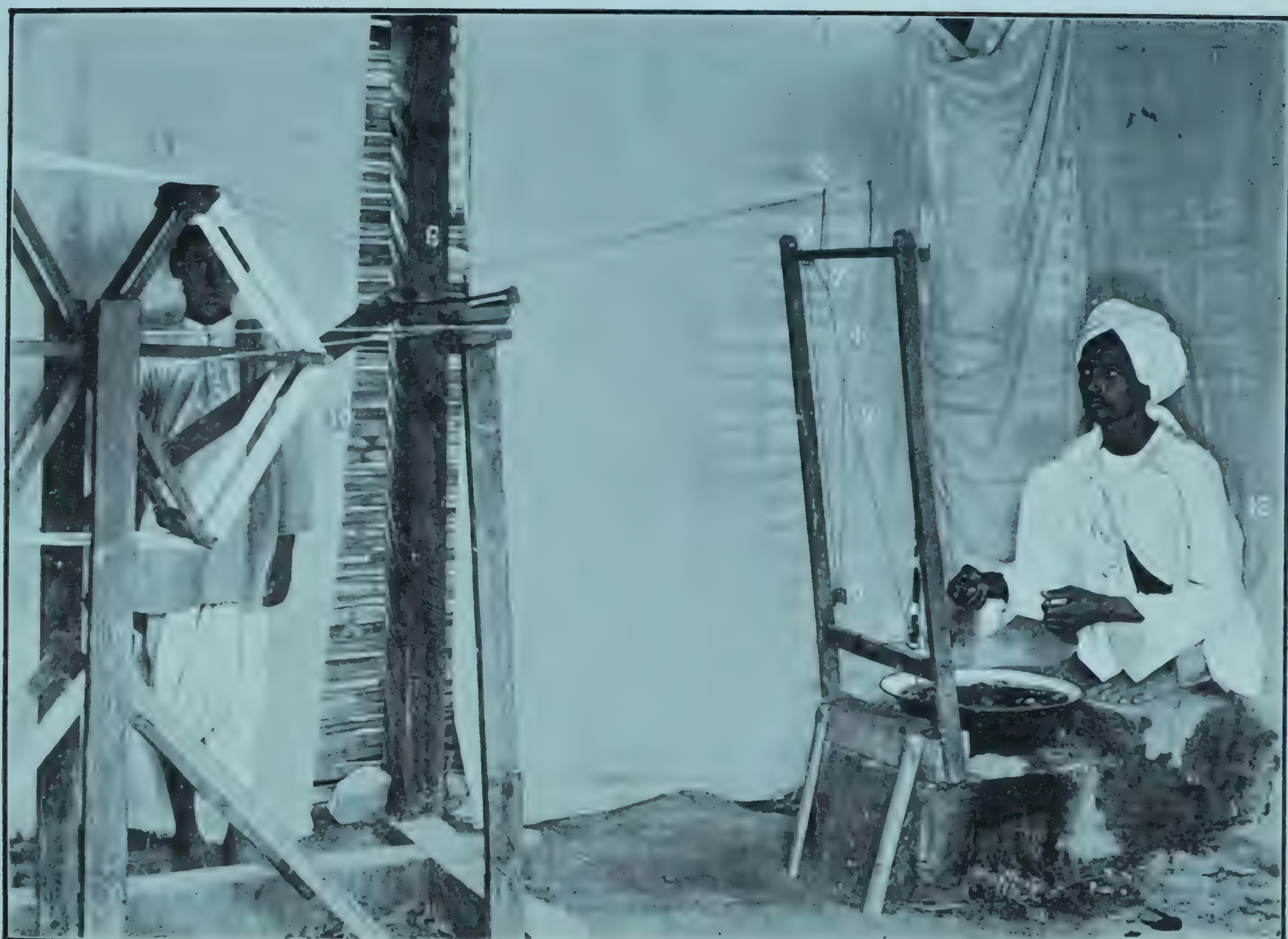
Change of reeling water.—When the water of the reeling pan becomes very turbid it is better to change it, otherwise the raw silk will lose its lustre and elasticity. It is not desirable to change the water frequently for every set of cocoons as the sericin will be dissolved in the fresh water more freely which will lose the unison and adherence of the filaments

and their lustre. It is also bad economy as large quantities of fuel and water will be consumed. In this connection it may be noted that we got some silk from the same weight of cocoons by the same reeler in (1) fresh water, (2) slightly turbid water, (3) very turbid water, (4) water containing solution of crushed pupæ. It was found that least time was taken in (2) and a greater quantity was produced in it though in lustre and colour it gave the palm to (1); in (4) the quantity of silk produced was greatest but the colour and lustre were very bad; in (3) the lustre was very bad. It can be safely concluded that water, a little turbid, is suitable for reeling. The turbidity must be constant; in the course of reeling the turbidity will increase, so it is advisable to replace a little of that turbid water by fresh water to make up that loss.

Improved method of reeling on the Bengal machine.—By the provision of two extra small aluminium, glass or wooden pulleys or wheels in the Bengal system of reeling machine we have managed to give about 200-350 twists. It should be noted that in the present system one thread is crossed with another thread only once or twice, but in Italy, France and Japan they give 200-350 twists which make the filaments round and well-united; on account of the friction the thread gets rid of a quantity of water and dries up quickly; lustre and other good qualities of silk are also well maintained.

One thread (5 to 6 filaments of univoltine and 10 to 12 filaments of multivoltine cocoons according to the Denier required) is passed through the button hole [Plate II, (1)] and above the upper wheel (2), then it is taken below the lower wheel (3) and the required number of twists or croisseurs is given with the former part of the same thread (4) and then it is passed through hooks (5) and (6) and the thread is then tied on the reel. The length of the twists should be about 7 or 8 inches; the upper angle (7) should be about 85° and the lower angle (8) should be about 25°. The porcelain button is supported by an iron plate which is attached with a hinge (9) so that if any knot or unreelable part of a cocoon comes with the filaments in the course of reeling, the minute hole of the button will prevent it from passing through the hole, but on account of the tension of the thread from the reel the plate will be raised by the help of the hinge (9) and thus it will prevent the thread from breaking if the winder (10) stops the reel (11) at once. One reeler (12) can reel 2 or 3 threads at a time. The part of the thread from 5 to 6 and 11 should be as straight as possible which can be done by raising the hook at 6.

PLATE II



IMPROVED METHOD OF REELING ON THE BENGAL MACHINE.

PLATE III

ANOTHER TYPE OF REELING MACHINE.
(Worked by a foot-pedal.)

We have been preparing round elastic and good thread at Pusa on the Bengal reeling machine by this arrangement and it is believed that if the Bengal reelers start on the lines suggested a great improvement in quality will result. This arrangemant can also be adopted with profit in Mysore and Assam. In this method the simple country appliance for reeling has been improved and yet its suitability for cottage workers maintained. The expenses to be incurred for the above two wheels (2) and (3) and the plate with the hinge (9) will not be more than 5 or 6 annas. Many can prepare them in their own place. Croisseur or twist can also be given in other ways in the Bengal machine but we recommend the above as it is very economical.

The Muga cocoons of Assam and the Tasar cocoons of the Central Provinces and Bihar can also be reeled on this appliance, but the process of boiling the cocoons is different.

Foot-pedal Reeling Machine.—There is a sedentary reeling machine sold by the Salvation Army, The Mall, Simla, for Rs. 25 on which a reeler can wind and reel at the same time. The reel is revolved by the movement of a pedal (Plate III). The required number of twists can be given on this machine, but there is no arrangement to keep the water of the reeling pan at one uniform temperature. The reeler also soon becomes tired as he has to use both his hands and feet.

Throwing the filaments.—In the course of reeling if the filament of one cocoon is exhausted or if the filament is broken it is necessary to add another new filament to keep up uniform Denier or thickness; this is rather a difficult process and should be learnt by practice and observation. At the time of throwing the following points should be borne in mind:—(*a*) The part of the filament, which is intended to be thrown on to the other filaments, should be very short, otherwise there will be a big knot. (*b*) At the time of throwing, the hand should be turned vertically downwards (not horizontally or transversely). (*c*) The cocoon, whose filament is to be thrown, should be placed very close to the other cocoons hanging from the button-hole, or long filaments will come out and mix with the other filaments in the reeling pan.

Standard number of cocoons for different Deniers.—The upper layer of all cocoons contains filaments of greater diameter than the lower layer so that the diameter of the filaments of 4 or 5 thick cocoons is equal to the diameter of 6 or 7 thin cocoons. The word "thick" here means "from which filament has not been reeled" and the word "thin" means "from which the filament has once been reeled, but which has

been broken in the course of reeling." The multivoltine races of India have $1\frac{1}{2}$ to $2\frac{1}{2}$ 'Deniers' but the univoltine races have 2 to 4 'Deniers.' Generally speaking, thick cocoons have thick filaments and thin cocoons have thin filaments. The following Table shows the number of 'thick' and 'thin' cocoons to be taken to produce threads of any required Denier :—

Denier of one cocoon.	Denier of raw silk wanted.	Number of thick cocoons to be thrown.		Number of thin cocoons to be thrown.
$1\frac{1}{2}$-2	8	3	+	2
„	9	4	+	1
„	10	5	+	0
„	11	0	+	7
„	12	4	+	3
„	13	6	+	1
„	14	5	+	3
„	15	4	+	5
„	16	8	+	0
„	17	8	+	1
„	18	7	+	3
„	19	8	+	2
„	20	3	+	10
2-$2\frac{1}{2}$	8	2	+	2
„	9	3	+	1
„	10	4	+	0
„	10	0	+	5
„	11	3	+	2
„	12	5	+	0
„	13	3	+	3
„	14	4	+	2
„	15	4	+	3
$2\frac{1}{2}$-3	8	2	+	2
„	9	3	+	1
„	10	3	+	2
„	11	4	+	1
„	12	4	+	2
„	13	3	+	3
„	14	4	+	3
„	15	5	+	2
	and so on.			

The filament at the time of throwing should be broken by pulling with the fingers or the filament should be held between two fingers and then it should be cut by pressing the thumb. The latter method is preferable. When the thread is broken the reel should be stopped at once and the broken ends should be tied as quickly as possible and the part left after the knot should be as short as possible. If there is any difficulty in finding out the broken end on the reel it can be found out easily by

rubbing the wound thread with the moistened hand. Sometimes the end goes inside the reeled thread on account of the quick rotation of the reel.

Button, Guider and number of revolutions of the Reel.—The button should be of porcelain or agate and its diameter should be about ½ inch and the hole of the button should be very fine or big knobs would pass through it and make the thread uneven. The height of the button from the water of the reeling pan should be about 3 to 5 inches. The guider helps the thread to wind uniformly on the reel; but for it the thread would be wound on one place of the reel. It helps to make unwinding easy and the thread to dry up quickly. The number of revolutions of the reel should be about 125 per minute if the worker is an expert. If the revolution is too rapid the filaments as well as the thread break easily, the reeler becomes very busy and consequently the thread becomes uneven and the elasticity and tenacity of the thread become bad. If the number of revolutions is too small it requires a long time to reel the cocoons which are overboiled by remaining a long time in the reeling pan.

The quantity of thread in one skein should be about 7 tolas. If the quantity is more the silk dries slowly and loses its lustre. It is also not economical to reel less.

Reeling water.—Water is the most important item in reeling as the quality of raw silk depends upon it. Rain water, spring or river water and deep well water are generally used for reeling. Of these rain water is the best. It is soft and comparatively pure. River water is generally soft as there is little mineral matter dissolved in it and hence it is good for reeling. Deep well water is rather hard.

If the water contains the compounds of calcium or magnesium the silk will be of a somewhat reddish colour, but if the quantity is small the colour of the silk will be very white and the silk will lose its lustre. If it contains iron or copper the colour will be somewhat brownish. If these compounds exist in large quantities the colour will be deep. There is no harm if 10 parts of calcium sulphate, 5 parts of chloride of lime, 5 parts of carbonate of lime, 5 parts of magnesium sulphate, 1 part of magnesium chloride, 1 part of magnesium carbonate, 0·01 part of iron sulphate, 0·01 part of chloride of iron, 1 part of aluminium sulphate, 0·5 part of aluminium chloride, 50 parts of common salt, 10 parts of potassium chloride, 0·05 part of sodium silicate, 0·05 part of organic matter or 0·1 part of copper sulphate remain in 10,000 parts of water. The above results have been obtained by the experimental station at Nishigahara, Tokyo.

In short, the salts of heavy minerals are most injurious in reeling silk, but fortunately there are few of these in natural water. Alkaline salts are abundant in natural water, specially lime and magnesium salts. Soft water is more suitable than hard water. Distilled water is not at all good for reeling as some alkaline matters are necessary for the easy winding of the filaments from the cocoons. Distilled water makes unwinding of the filaments difficult, while a minute quantity of alkaline matter, dissolved in the water, makes unwinding easy.

Remedy.—The two following practical remedies may be adopted :—(1) The aeration of water, (2) The filtration of water. By aeration bicarbonates are precipitated and water becomes softer, but other salts such as sulphates and chlorides are not precipitated. By filtration some of the salts are absorbed by the filter materials. Bone and animal charcoal are the best materials for filtration, but as they are expensive wood charcoal, coarse and fine sand are recommended. It is advisable to pass the water through these materials (charcoal, coarse sand and fine sand) to the reservoir. The capacity of the reservoir is sufficient when it is capable of retaining or storing water for the consumption of 3 days. The depth of water in the reservoir or tank should be about 3 feet. In winter the filter materials should be changed every two months ; in summer once a fortnight. These materials can be used again by washing and drying them in the sun.

The quantity of water consumed by a reeler is about 4 or 5 mds. per day. Ordinary reelers should use big earthen jars for storing water.

Clarke's method of softening water.—Ninety maunds of water to be softened are poured in a large cistern. About 1 oz. of quicklime is necessary to soften the above quantity if it is of ordinary hardness. The process of softening is as follows :—At first 6 maunds of water are put in a cistern or jar into which 1 oz. of quicklime is poured in the state of milk of lime ; then the water is vigorously stirred by means of a rod and the remaining water is mixed with it. The water is allowed to settle for about 16 hours and then the surface water can be safely used for reeling. Care must be taken not to add too much quicklime as it injures raw silk. For testing the exact quantity of lime necessary to soften the water the following method is adopted. A drop or two of silver nitrate solution is poured into a small cup containing the above water ; if the colour is dark brown it means that excess of lime has been used and more water should be mixed with it, but if the colour is light yellow it means that the correct quantity of lime has been used ; if the solution shows no

colour more lime is necessary to soften the water. While testing with silver nitrate 2 drops of 5 per cent. solution of silver nitrate will be enough for a cup of water.

Clarifying muddy water.—Alum or aluminium sulphate should be added to the muddy water. If the salt is powdered and dissolved in water, mud and other impurities are deposited at the bottom and the surface water becomes clear. It is advisable to use the mixtures of the above two salts generally. 0·5 to 1·36 gms. (of equal quantities of these two mixtures) are added to about 200 seers of water (according to the degree of muddiness). The powdered mixtures should be dissolved in hot water and then thoroughly mixed with the muddy water. The water can be used after allowing it to settle for 8 to 12 hours.

Quality of silk.—The quality of raw silk is determined by the following :—(1) Denier, (2) Elasticity, (3) Tenacity, (4) Knobs, (5) Lustre, (6) Colour, (7) Softness to the touch, (8) Moisture, (9) Twist, and (10) Quantity of Gum.

The Denier is the unit of weight used in France, 450 metres of thread weighing 0·05 gm. being equal to 1 Denier legale ; 1 Old French Denier is equal to 476 metres weighing 0·0531 gm., and 1 international Denier is equal to 500 metres weighing 0·05 gm. It is not possible to ascertain the exact denier of a skein of thread. From the different parts of the same skein 450 metres of thread are taken in 3 or 4 lots ; then they are weighed separately on the denier scale or balance. The average denier is considered to be the actual denier of the skein. The Americans generally like to have 13 deniers and the Europeans 10 deniers. In Bengal filatures silks are reeled from 16 to 20 or 20 to 25 deniers and in Kashmir and Jammu 12 to 14 or 15 to 18 deniers and sometimes 10 to 12 deniers. The Bengal country reelers reel thread of 40 to 60 deniers. A sample of silk marked 20-25 for example means that the denier varies from 20 to 25 deniers. On the Eprouvette 450 metres of reeled silk can be measured accurately. The denier is affected by good or bad cocoons, by good or bad reeling machines, by the skilfulness of the reeler and by the number of revolutions of the reel. The price of a good Denier scale or balance is about Rs. 30 while that of an Eprouvette or testing machine is about Rs. 65.

Elasticity and tenacity.—Elasticity and tenacity are measured by the Serimetre, but they can only be estimated approximately. Fifteen or twenty parts of the thread used in deniering are examined on the Serimetre. The average of these is considered as the elasticity and

tenacity of the skein. The value of these two qualities is affected both by the individual and corporate filaments composing the thread, drying and storing of cocoons, the water used in the reeling and boiling pan, the number of threads and the adhesion of filaments in a thread. On an average if the denier is 9 the tenacity should be about 34 gms. and elasticity 101 mm., *i.e.* 20 per cent. ; if the denier is 12, tenacity should be 44 gms. and elasticity 105 mm., *i.e.* 21 per cent. ; if the denier is 15, tenacity should be 53 gms. and elasticity 109 mm., *i.e.*, 22 per cent.; and if the denier is 17, the tenacity should be 60 gms. and elasticity 109 mm., *i.e.* 22 per cent. The price of a Serimetre is about Rs. 90.

Knobs and knots.—It is not possible to get any raw silk without any knobs or knots, but these should be as few as possible. They can be reduced by good stifling, storing and drying of cocoons, by selection of cocoons, by good boiling, by skilful tying and throwing. There are natural knobs which cannot be avoided but they can be lessened to a great extent by careful reeling and drying. On the Eprouvette 450 metres of reeled silk are wound and the number of knobs can be counted in this length of thread. There is also a separate machine for examining knobs. In 450 metres, for fine silk 2 large knobs and 250 small knobs (hairs), for medium silk 3 large knobs and 255 small knobs and for coarse silk 3 large knobs and 260 small knobs are allowed.

Lustre and colour.—The lustre and colour of silk skeins are examined in a dark room, the walls, floor and ceiling of which are cemented with black tar and the refracted rays of the sun are allowed to enter into the room in a slanting way.

Softness.—Softness of silk is examined by touch.

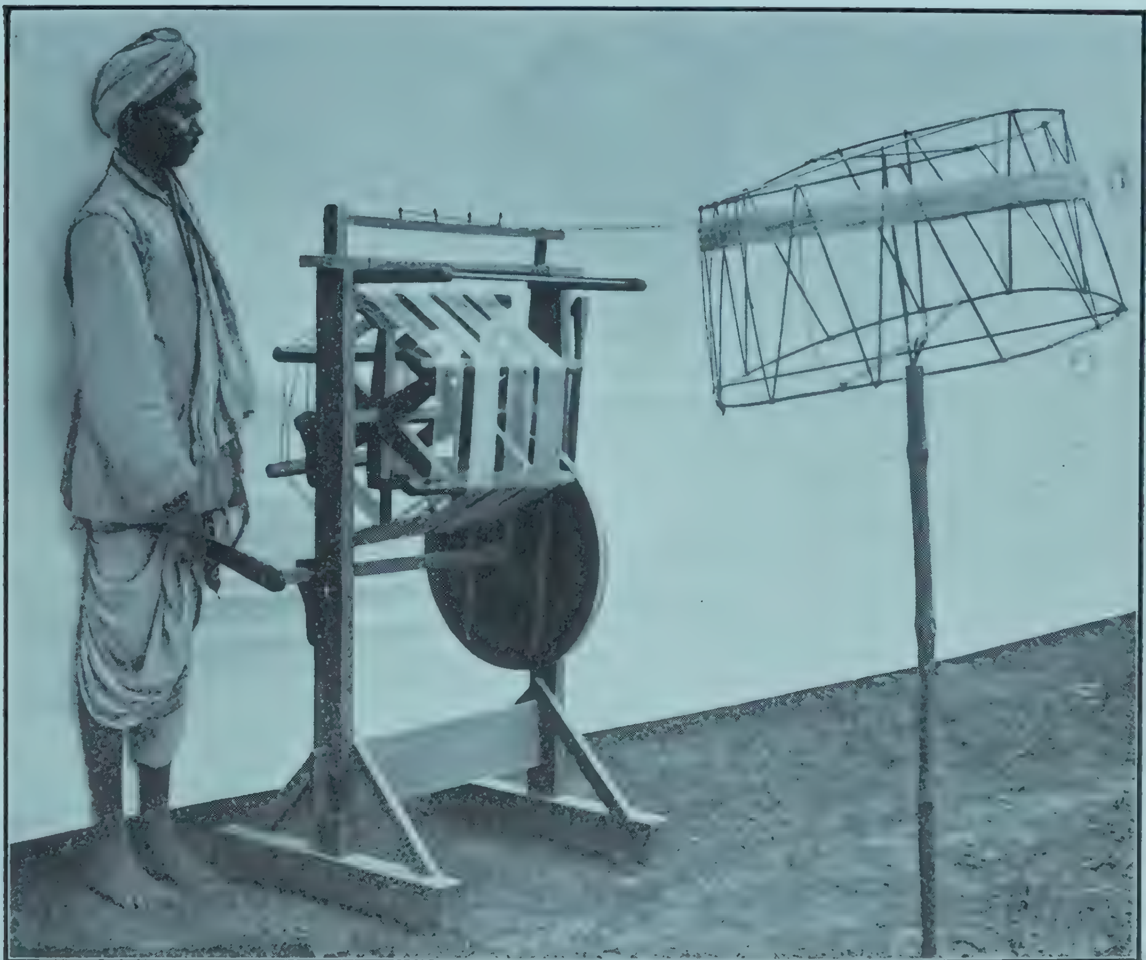
Moisture.—Silk is quite hygroscopic and under favourable circumstances it will absorb as much as 30 per cent. of its weight of moisture and still appear dry. It is therefore customary to determine the amount of moisture in each lot at the time of export.

Gum.—By boiling a sample of raw silk in 20 per cent. well-neutralised soap and water 50 to 60 times the weight of silk for about $2\frac{1}{2}$ hours the quantity of gum it contains may be ascertained. The sample should be weighed before and after boiling in the dry state. Generally gum should be about 25 to 30 per cent. of the weight of silk.

For ordinary reelers these testing machines are not necessary.

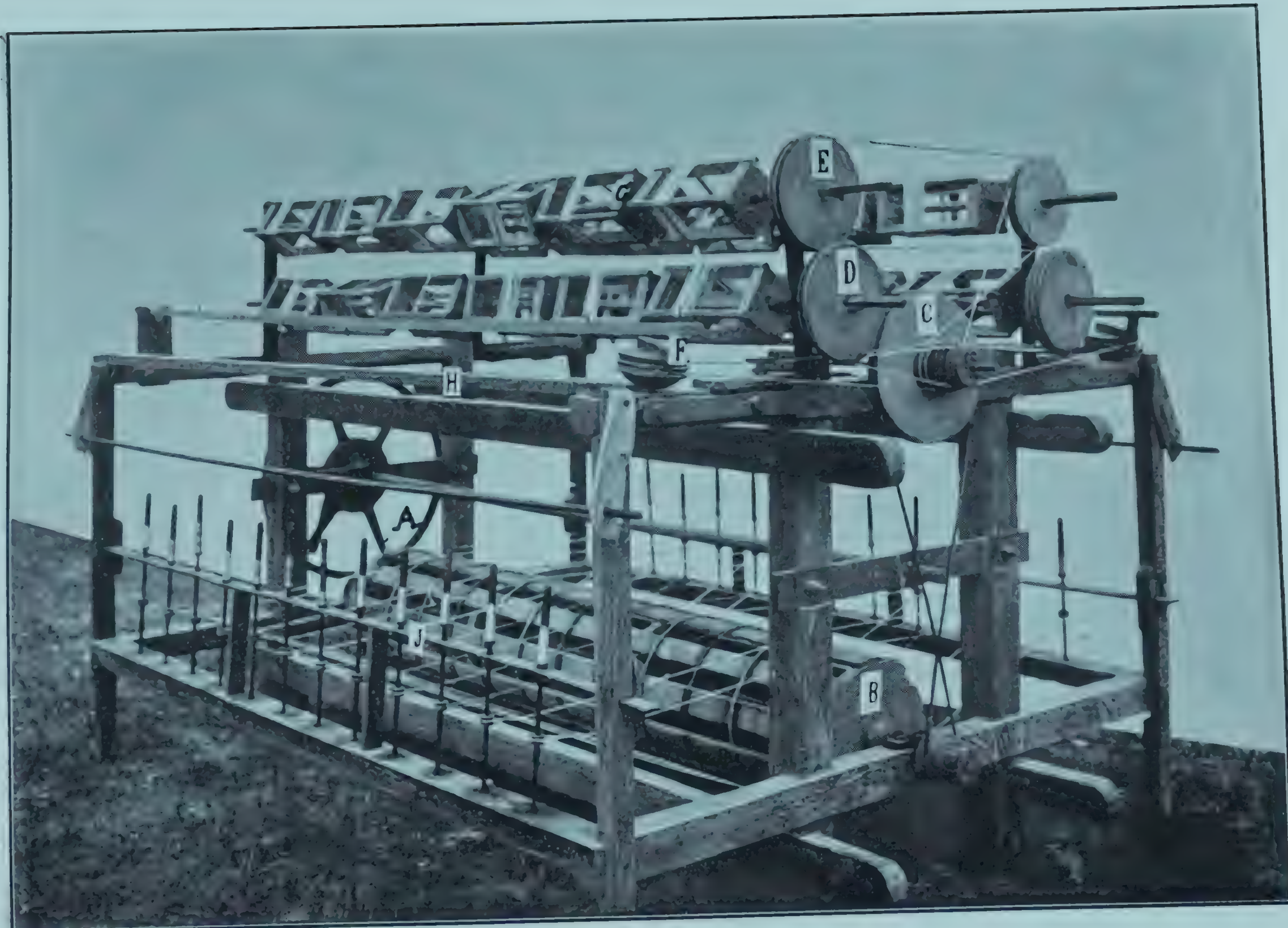
Re-reeling.—For export raw silk should be re-reeled on a re-reeling machine ; but for home consumption re-reeling is not necessary. There is a great demand for good reeled and re-reeled silk in Europe and

PLATE IV



RE-REELING MACHINE.

PLATE V



SURAT TWISTING MACHINE.

America. Re-reeling can be done on the Bengal reeling machine after putting a skein on a *cherky*. Three or four skeins can be re-reeled easily at a time by small boys or girls.

The process of re-reeling is as follows:—One skein of silk (1) is placed on a *cherky* (2). The end of the skein is passed through the hook of the guider (3) and then tied to the reel (4). Now if the reel is turned the silk will be wound on the reel (*vide* Plate IV).

Twisting.—Reeled silk can be twisted profitably on the Surat twisting machine. In Bengal, the United Provinces and other places raw silk is twisted on the *Dol*. The working of the twisting machine is as follows:—The bobbins with the raw silk are placed on the iron rods at J (see Plate V). If the toothed wheel (A) is turned it revolves also the big drum (B) which is connected with the 24 bobbins with separate belts of thread; these and the wheel (C) are turned with it. Now the wheel (C) is connected with the wheels F, D and E, and these are turned with it; so that by the revolution of the toothed wheel (A) the reels (G) are turned and single or double threads are wound on them from the bobbins after being twisted. One single thread from the bobbin is allowed to pass through the hooks at H and on the rod connected with F so that it goes straight to the reel and winds up there without getting detached. The wooden rod connected with (F) moves to and fro so that the twisted thread is wound on a width of 3 or 4 inches of the reel and not one layer upon another.

Probable expenditure and receipts of a small reeling factory of 10 pans.

Expenditure.

	Rs.
House	60
10 Reeling Machines	150
Miscellaneous	50
Pay of 10 reelers and 10 winders for one month	150
Fuel	75
Water	13
Oil and sundries	5
75 maunds of cocoons at Rs. 25 per maund	1,875
* Total	2,378

Receipts.

	Rs.
Price of $187\frac{1}{2}$ seers of reeled or raw silk (done by the ordinary Bengal reelers) at Rs. 14 per seer or 2 lbs.	2,625
Price of waste cocoons and ribbon waste	75
Total	2,700

* *N.B.*—Cartage, supervision, interest on the capital and cost of drying and storing of cocoons have not been taken into consideration. 40 seers = 1 maund = $82\frac{1}{2}$ lbs., 1 *tola* = 11·3 gms.

Reeling is a profitable industry and can be carried on with hired labour on a big or small scale. It should only be done on a large scale after experience has been gained.

Packing for export.—The end of each skein should be kept in a prominent place in the middle of the skein, tied with a little white cotton thread so that there will be no difficulty in its being picked out by the weavers at the time of unwinding it. To prevent it from getting entangled in the skein the latter should be tied smoothly near the end which should also be tied with it. All these operations should be done when the skein is on the reel. Before preparing the skeins the raw silk should be perfectly dry; they should be neat and uniform in appearance and should be made by expert hands. About 30 skeins should be put in one bundle keeping the top part of all the skeins on the same level. The bundle should be tied with thick and coarse cotton thread neither too tightly nor too loosely; then it should be wrapped in some strong and smooth paper (parchment better); 15 of these bundles are packed together and make what is called a bale. The bale should be wrapped with wax cloth and packed tightly in a strong dealwood box. The boards of the box must fit tightly and some cross pieces of wood or iron bands should be used to prevent the box from breaking. The box should be wrapped in gunny and then addressed and marked. It will then be ready for despatch.

Advice.—If any doubts arise reference can always be made to the Imperial Entomologist, Pusa, Bihar, for advice and information which will be given to inquirers as far as possible.

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Bulletin No. 45 1914

Agricultural Research Institute, Pusa

The Acid Secretion of the Gram Plant, *Cicer arietinum*

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1914

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Superintendent Government Printing, India, Calcutta

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THE ACID SECRETION OF THE GRAM PLANT, *Cicer arietinum*

Introductory.

The most common of all the pulse crops in India is gram (*Cicer arietinum*) which occupies annually more than thirteen million acres. It grows almost exclusively as a *rabi* crop and, in growing, it has long been known that the plant secretes and deposits an acid liquid all over its surface. The existence of this secretion, which can hardly remain unnoticed by anyone who walks through a field of gram in the early morning, has long been known. Collected in a way shortly to be described, it is used in medicine fairly extensively in Western India at any rate, being known in Marathi by the name '*Amb.*' The interesting nature of this secretion attracted the writer's attention some years ago, and the present is an account of the results of an investigation into its nature, its variations, its quantity, the mechanism of its production, and the possibility of making a larger use of it than is done at present.

The history of our knowledge of this secretion goes back more than a century, for Hove in 1787* noticed its utilization in Northern Gujarat where he says " On the road to Dowlat (a village about 7 miles from Dholka), we met with numerous women who gathered the dew of the grain, called by the inhabitants *chana* or gram, by spreading white calico cloths over the offspring, which was about two feet high, and so drained it out into small hand-jars. They told me that in a short period it becomes an acid, which they use instead of vinegar, and that it makes a pleasant beverage in the hot season when mixed with water : as likewise they used it as an antidote for the venom of pernicious snakes.......... I tasted the dew, but found it of no particular taste, except rather softer than common water, as it is peculiar to the dew."

---

* Hove—*Tours for Scientific and Economical Research made in Guzerat, etc., in 1787-88.* Bombay 1855.

B

Whether as a result of Hove's observations or no, a considerable amount of interest was roused in the beginning of the nineteenth century, and the secretion was examined by several European chemists,* the principal result of which was to indicate that the secretion is acid, and that the acidity it contains is due to malic acid, oxalic acid, and a small quantity of acetic acid.

This represents the state of information which has remained on the subject to this day; the numerous references to the acid secretion of the gram plant (which are found summarised in Watt's *Dictionary of the Economic Products of India*, and in the *Pharmacographica Indica*†) adding nothing further of any importance.

A preliminary study of the secretion from the gram plant, both as collected by ourselves by washing the plants with water, and as bought in the bazaar, was first made. The liquid was boiled with lime water in the presence of slight excess of acetic acid. A white precipitate was formed which proved to be calcium oxalate, showing the presence of oxalic acid in the secretion.

The remaining liquid was neutralised with lime water, and evaporated until a finely crystalline precipitate was obtained. The precipitate was rapidly shown to be either calcium tartrate, citrate, or malate. The actual nature of the precipitate was shown by the following tests: —

(1) On addition of lead acetate to a solution of the acid or of the calcium salt, a white precipitate was produced, soluble on heating the solution. This is a characteristic of malic acid.

(2) On addition of β-naphthol in strong sulphuric acid to the acid liquid or to a solution of the calcium salt, a yellowish green coloration was produced, which turned bright yellow on heating and bright orange on dilution with water. This is a very delicate test to distinguish malic acid from other organic acids.‡

(3) The silver salt of the acid was prepared, by adding silver nitrate to a solution of the calcium salt, and from this the molecular weight of the acid determined.

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* Dulong—*J. Pharm.* XII-110; Vauquelin.—*Scher. Journ.* VIII-279, Deyeux—*Scher. Journ.* II-270; IV-66. Dispan,—*Scher. Journ.* III-449; VIII-272. Also see Boussingault.

† Watt—*Dictionary of the Economic Products of India*, Vol. II, pages 282-4. *Pharmacographica Indica*, Vol. I, page 489.

‡ *Journal, Soc. Chem. Ind.*, 1897, page 361.

0·195 gramme of the silver salt gave 0·121 gramme of silver on heating. Taking the acid to be dibasic, this is equivalent to a molecular weight of 134·09. The actual molecular weight of malic acid is 134.

There is therefore no doubt that the acid which remains after the separation of the oxalic acid is malic acid,—and the composition ascribed to it by the chemists above quoted in the early part of the last century was correct. It consists, in fact, essentially of malic acid, with a varying proportion of oxalic acid, and a trace of volatile acids only amounting to 0·2 per cent. A detailed study was therefore undertaken, of which an account will be given dealing with the following points :—

(*a*) The amount of acid secreted by the gram plants at various stages of their growth, and its nature at these stages.

(*b*) The method of production of the acid, that is to say whether its production is a continuous process.

(*c*) The part or organ of the plant involved in producing the acid secretion.

(*d*) The total amount of acid produced per acre.

Experimental.

(*a*) *The Amount and Nature of Acid secreted at various stages of growth.*

The investigation of the amount of acid secreted by the plants at various stages was conducted by growing the gram plants under precisely similar conditions in pots sunk in the ground and containing the same kind of soil. Three seeds were sown in each pot, and each week the plants in one pot were uprooted, their roots cut off, and they themselves carefully washed with water. After extraction the plants were dried and weighed so that the amount of acid could be calculated on the basis of the dry matter contained in the plants. The total acidity in the extract was determined by titration with decinormal caustic potash. In another portion the volatile acids were distilled with steam, and the oxalic acid determined in the non-volatile portion by the precipitation with lime water. The remaining acidity was due to malic acid and was calculated as such.

The following table shows the results of such actual determinations at every stage in the life of the plant. The plants used for the examination of the acids during the early stages in the growth of the plant were a different series from the others and were planted later. All

the pots however received the same treatment except that those marked 'P' in the table were pruned in the fifth week of their growth, while the others marked 'N' were allowed to grow without any interference :—

Acid in Gram Plants.

Date on which acids were extracted.	Age of plants in weeks.	Total acids (in gms. KHO per 100 of dry matter).	"Malic acid" per 100 gms. of dry matter.	"Oxalic acid" per 100 gms. of dry matter.	"Volatile acids" per 100 gms. of dry matter.	REMARKS.
21st January 1914 .	2	0·36	...	...	...	Tender Plants.
7th " " .	3	0·58	...	...	...	
14th " " .	4	0·75	...	...	...	
12th February 1914 .	5	1·3	...	...	...	Flowering.
19th " " .	6	1·0	...	...	...	
26th " " .	7	1·0	...	...	...	Pods appearing.
5th March 1914 .	8	1·87	...	...	...	Pods with seeds not well developed.
12th " " .	9	1·94	...	...	...	
16th December 1913 .	10 P. 10 N.	2·3 2·0	2·58 2·26	0·11 0·1	... ...	Pods with seeds well developed in some pods.
24th " " .	11 P. 11 N.	2·3 1·9	2·52 2·1	0·15 0·15	0·01 0·01	
31st " " .	12 P. 12 N.	2·7 2·2	3·0 2·4	0·15 0·14	0·01 0·006	Seeds developed in many pods.
7th January 1914 .	13 P. 13 N.	2·85 2·2	3·2 2·6	0·1 0·14	0·004 0·004	Seeds developed in all pods.
14th " " .	14 P. 14 N.	2·6 2·5	3·0 2·8	0·1 0·12	0·005 0·004	Leaves turning yellow.
21st " " .	15 P. 15 N.	2·3 1·9	2·4 2·1	0·1 0·1	0·005 0·004	Leaves yellow. Pods drying.
28th " " .	16	2·1	2·3	0·13	0·004	Pods almost all dry.
4th February " .	17	1·5	1·6	0·16	0·01	The whole plant dry.

The figures in this table are of considerable interest.

Total acidity.—If we express the total acidity as the number of grammes of caustic potash required for neutralisation for every hundred grammes of dry matter, it will be at once noticed that there is a marked

and fairly sudden rise in the amount of acidity at the time of flowering, after which the quantity remains steady until the pods are formed. When this occurs there is another rapid rise in the quantity of acids produced which is maintained until the plants, including the pods, begin to dry when the quantity rapidly declines. It is evident that the maximum amount of acid corresponds with the full development of the pods, and before they have begun to dry.

Malic and Oxalic Acids.—The proportion between these acids is wonderfully constant from the tenth week onwards. No direct determination of the two acids was made at earlier stages than this, as the total quantity obtained from the plants was very small. In the remainder of the life of the plant the acid, on the average, consists of 94 per cent. of malic acid and 6 per cent. of oxalic acid. The relative amount of oxalic acid is highest when the plants are dry, but for the rest is very constant. The following table shows the composition of the acids in each week after the tenth, in the normally developed plants, without pruning :—

Acids in Plants grown normally.

Week.	Percentage Composition.		
	Malic Acid.	Oxalic acid.	Volatile acids as Acetic Acid.
	Per cent.	Per cent.	Per cent.
10th week	95·8	4·2	Not determined.
11th "	92·9	6·6	0·5
12th "	94·3	5·5	0·2
13th "	94·7	5·1	0·2
14th "	95·8	4·1	0·1
15th "	95·3	4·6	0·1
16th "	94·5	5·4	0·1
17th "	90·4	9·1	0·5
Average .	94·2	5·6	0·2

In the plants pruned in the fifth week the relative amount of the two acids does not differ materially from that in the plants grown naturally as the following table will show :—

Acids in Pruned Plants.

Week.	Percentage Composition.		
	Malic acid.	Oxalic acid.	Volatile acids as Acetic Acid.
	Per cent.	Per cent.	Per cent.
10th week	95·9	4·1	Not determined.
11th „	94·0	5·6	0·4
12th „	94·9	4·8	0·3
13th „	96·8	3·0	0·2
14th „	96·6	3·2	0·2
15th „	95·8	4·0	0·2
Average .	95·7	4·1	0·2

Effect of pruning on acidity.—While however the composition of the acids from the normally grown and from the pruned plants is approximately the same, the amount of dry matter per plant is greater with the pruned plants and the amount of acids per one hundred parts of dry matter in the plant is considerably greater. The difference in the amount of dry matter per plant is shown in the following table :—

Week.	Pruned Plants. Dry matter per plant.	Normally grown plants. Dry matter per plant.
	Grammes.	Grammes.
10th week	4·3	3·8
12th „	8·7	8·1
13th „	11·2	8·9

The increase in the amount of acid produced per 100 parts dry matter is considerable, thus—

(1) in the 10th week, the pruning increased the amount of acidity (total) by 15 per cent.;

(2) in the 11th week, the pruning increased the amount of acidity (total) by 21 per cent.;

(3) in the 12th week, the pruning increased the amount of acidity (total) by 23 per cent.;

(4) in the 13th week, the pruning increased the amount of acidity (total) by 30 per cent.;

(5) in the 14th week, the pruning increased the amount of acidity (total) by 4 per cent.;

(6) in the 15th week, the pruning increased the amount of acidity (total) by 21 per cent.

This is probably due to the increase in the number of pods by pruning as it will be shown later that the acid-secreting apparatus is most highly developed on this part of the plant.

(*b*) *The Method of Production of the Acid.*

An interesting question arose at an early stage in the present investigation, as to whether the production of acids by the gram plant is a continuous process, and, if so, how rapidly it takes place. To investigate this point, four strong plants aged ten weeks were selected. Of these plant No. 1, was washed daily, plant No. 2 was washed every second day, plant No. 3 every fourth day, and plant No. 4 every sixth day. The amount of acids in the washings was determined as usual by titration with decinormal caustic potash, and the amount is indicated in the following table by the number of cubic centimetres required.

Acids from Plants washed at different intervals.

(In cubic centimetres of decinormal caustic potash required to neutralise, per plant.)

Days.	Washed every day.	Washed every second day.	Washed every fourth day.	Washed every sixth day.
(Plants 10 weeks old.)				
First day	36·0	37·1	33·4	31·3
Second day	5·2	...	...	...
Third day	6·4	13·1	...	...
Fourth day	5·7	...	...	...
Fifth day	6·1	12·3	27·4	...
Sixth day	6·2	...	...	...
Seventh day	4·9	10·9	...	37·8
Eighth day	3·1	...	...	...
Ninth day	5·1	10·0	18·9	...
Tenth day	Omitted.	...	...	...
Eleventh day	7·2 (two days.)	8·4	...	...
Twelfth day	4·3	...	...	...
Thirteenth day	4·4	8·4	23·4	37·2
Fourteenth day . . .	4·7	...	...	...
Fifteenth day	5·6	14·0	13·0	15·8
Total excluding first washing .	68·9	77·1	82·7	90·8
Total including first washing .	104·9	114·2	116·1	122·1

One thing appears clear from these figures. The plant is continually producing acid, and it is secreted in sufficient quantity for the amount normally found on the plant to be produced in a week. It matters little apparently whether the washing be done daily or at less frequent

intervals: in all cases the original amount, approximately, is reproduced after six days, thus :—

—	Original amount acid.	Acid obtained after six days.	Acid obtained after second six days.
1. Plant washed daily	36·0	34·5	24·1
2. Plant washed every two days . .	37·1	36·3	26·8
3. Plant washed every six days . .	31·3	37·8	37·2

This does not go on, however. The continual washing appears to exhaust the acid-producing power of the plant, and in the second period the quantity produced, with frequent washing, is much smaller—while when the washing only took place after six days, it is undiminished.

It is evident, on the other hand, that washing up to a certain point stimulates the production of acid. As has already been seen in the first table, the total acidity which can be obtained from a gram plant which has not been previously washed, while increasing towards maturity, yet does not increase very much after the eighth or ninth week of growth. But the continual washing in the present experiment has led to the reproduction in fourteen days of from two to three times the original amount. This is shown in the following table :—

—	Acidity on first washing per plant (c. c. decinormal potash).	Acidity in fourteen days following, per plant (c. c. decinormal potash).	Percentage increase of total acids by washing.
			Per cent.
1. Plant washed daily	36·0	68·9	191
2. Plant washed every two days . .	37·1	77·1	208
3. Plant washed every fourth day .	33·4	82·7	248
4. Plant washed every sixth day . .	31·3	90·8	290

If one looks, therefore, on the production of acid by the gram plant as a possibly commercial process, the above conclusively proves that washing the plants often will always increase the quantity of acid

secreted,—and the only thing now to determine is the most favourable interval between the washing of the plants with a view to collect the largest quantity of acid. So far as the writer's experiments go, this interval may be fixed at six days. With shorter intervals, as already indicated, the quantity produced tends to decline rapidly ; if the acids are only taken once in six days it remains constant within the limit of these experiments.

(c) *Part of the Plant which produces acid secretion.*

The production and secretion of malic and the other associated acids in the way described is such a curious phenomenon that it became of great interest to ascertain the actual organs of the plant engaged in producing them. In doing this the writer has had the kind assistance of Mr. H. M. Chibber of the Poona Agricultural College which is herewith acknowledged.

The gram plant is a small herb with fibrous roots. The entire plant above the cotyledons is covered with hairs of one kind or other. In the flower, the calyx and ovary are also provided with this hairy covering. The hairs are of two kinds, simple, and glandular. The simple hairs are unicellular, thickwalled and empty, with hardly any calibre. They measure about a third of a millimetre in length, and are present everywhere except on the ovaries or pods. The glandular hairs are found on all parts, intermixed with the simple hairs, except on the ovaries on which only glandular hairs are present.

The leaflets have hairs of the two types mentioned above, on both the surfaces, but the lower surface is more densely hairy. About three glandular hairs and twelve simple hairs are present per square millimetre of the upper surface, while as many as eight glandular and twenty-six simple hairs go to the same area of the lower surface. The glandular hairs are thickest on the pods ; even stomata are absent. These hairs on a full sized pod numbered about twenty to a square millimetre. They are also longer on this organ of the plant than elsewhere. Here they measure about four-fifths, while elsewhere only one-half a millimetre in length. But for the differences in the density and size noted above the glandular hairs are similar all over the plant. Each hair is composed of a multicellular stalk, and a multicellular knob. The knob is about a sixth of the total length of the hair, and is about twice as long as it is broad. The knob is in other words oval in outline. As

regards contents, the stalk cells are clear, the knob cells alone are filled with highly granular faint yellow contents. The knobs show a distinct acid reaction, and their contents are coloured an intense yellow with dilute caustic potash solution.

The peculiarity of the gram plant is then that it has hairs with knobs and these especially on the pods. In order to ascertain whether these hairs have anything to do with the production of acid, an experiment was made as follows.

Some gram plants were taken and the acids obtained by washing the pods and by washing the rest of the plants were separately extracted and the dry matter of each weighed separately. The results were found to be as follows :—

——	Malic acid per 100 gms. of dry matter.	Oxalic acid per 100 gms. of dry matter.
	gms.	gms.
Pods with seeds removed . . .	16·24	0·7
Gram plant after removing the pods .	0·5	0·02

This shows that the amount of acid produced is far greater where the knobbed hairs are most abundant than anywhere else in the plant. While not proving that the knobbed hairs are the actual producers of the acid, it renders this conclusion a probable one.

(*d*) *The Amount of Acid produced per acre.*

So far the nature and the quantity of the acid secretion, the stage in the plant's development when it is most abundantly produced, and the organ which probably produces the acid have been considered, but only individual plants have been cited. It is important to ascertain what is the amount of acid which can be obtained from a field of gram as ordinarily sown. The method, usual among the people, of collecting the acids was adopted, and was as follows :—A piece of clean cloth was tied to a stick. The piece of cloth was first dipped in water and the water wrung out as far as possible. This cloth was then slowly drawn over the gram plants to absorb the acid liquid on the plants. When the cloth was sufficiently wet it was wrung into an earthenware vessel and this was continued till the whole plot had been treated. From the liquid thus collected from a plot of $\frac{1}{160}$ acre, the acids were estimated and

calculated for one acre. The acids were removed from the plot every week from the fourteenth to the eighteenth week.

The following table shows the acids calculated for one acre :—

Age of the crop in weeks.	Malic acid per acre for that week in grammes.	Oxalic acid per acre for that week in grammes.
14th week	384	16
15th "	384	16
16th "	279·7	11·9
17th "	217	9
18th "	78·7	3·3
Total .	1,343·4	56·2

The removing of acids was started too late to get the maximum quantity.

If one calculates from these results the probable yield in acid of a field, from the ninth to the eighteenth week, the total amount of malic acid per acre will be 2,686·8 grammes. The removal of the acids from one acre of gram takes one man about four hours, and hence the cost of obtaining the above amount (2,686·8 grammes) of malic acid will be about R14.

It is well known that the removal of this acid secretion from the plants in the manner here described has no effect whatever on the vitality of the plants. In the experiments recorded above even the daily washing of the plants with water did not apparently affect them, and any malic acid thus produced will be obtained without in any way injuring the crop, or reducing the yield of the seed.

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HONEY BEES.

EXPLANATION OF PLATE I.

Honey Bees.

Fig. 1.—Queen of the Italian Variety of the European Bee (*Apis mellifica*).
„ 2.—Worker ditto ditto ditto.
„ 3.—Drone ditto ditto ditto.
„ 4.—Queen of the Indian Bee (*Apis indica*).
„ 5.—Worker ditto ditto.
„ 6.—Drone ditto ditto.
„ 7.—Queen of the Little Bee (*Apis florea*).
„ 8.—Worker ditto ditto.
„ 9.—Drone ditto ditto.
„ 10.—Worker of the Rock Bee (*Apis dorsata*).

All the figures are magnified about two-and-a-half times.

Bulletin No. 46 1915

Agricultural Research Institute, Pusa

BEE-KEEPING

BY

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Assistant to the Imperial Entomologist

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

Agents for the sale of books published by the Superintendent Government Printing, India, Calcutta.

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Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore and Calcutta.

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PREFACE.

WE have in India three important classes of insects which yield products useful to man. They are Silkworms, Lac-insects and Honey-bees. Practical directions for the cultivation of both Eri and Mulberry Silkworms and of Lac have already appeared in this series (*Pusa Bulletins* Nos. 29, 39 and 28). The present Bulletin provides similar information regarding Honey-bees and Bee-keeping in India.

Thirty-five years ago Government inquired into the question of Bee-keeping in India and published the replies from Local Governments under the title of "A Collection of papers on Bee-keeping in India" (Calcutta; 1883). A few years later Mr. J. Douglas brought out a small Handbook of Bee-keeping in India (Calcutta; 1884); this is now long since out of print and unobtainable. After this the subject seems to have languished for many years, although bees were kept in frame hives by a few people in some of the Hill Stations. In 1907-08 a few colonies were brought to Pusa from Simla but these were not successful and soon died out. In 1910 and again in 1911 we imported European Bees and tried these at Pusa and in the latter year I published notes on Bee-keeping and on Wax-moth in the *Agricultural Journal of India*, Vol. VI, Part IV, and projected a further series of articles and a practical manual on the subject. My transfer to Madras and pressure of other more urgent work has delayed this and this Bulletin has been prepared for present use by Mr. C. C. Ghosh, who has acquired some knowledge of bee-keeping mainly under my direction. It is frankly to a large extent a compilation from various excellent manuals on the subject prepared in Europe and America but these of course do not deal with Indian bees or Indian conditions, nor are these books readily accessible in India; so that it has been necessary to add some account of Indian bees and of the modified form of Standard Frame-hive which has been found practically useful with *Apis indica,* the only Indian wild bee which it seems possible to domesticate in any way.

It is hoped that this Bulletin may be useful to bee-keepers and would-be bee-keepers. There is a large scope for bee-keeping in India, especially in the Hills. The native Indian bee is common, easily obtainable almost everywhere and easily kept in frame-hives, except that it often shows a tendency to desert the hive after a few months; a drawback is its small yield of honey, which only averages about five or six pounds per hive yearly. In orchards and similar places, where bees are required to pollinate flowers it should, however, be well worth while to keep these bees for this end alone.

B

Bee-keeping cannot be looked on as a source of income in India except perhaps in a few exceptional localities and even then only in cases where the bee-keeper is a practical expert willing and able to take the necessary trouble to attain results; bee-keeping is not a short cut to fortune anywhere, probably less so in India than in most other countries. It is necessary to say this because we frequently receive inquiries from correspondents who suppose that they have nothing to do but get a few bees and leave them to produce honey and wax which their owner has only to collect and sell without any trouble or expense. We can only recommend beginners to start on a small scale, at first with two or three hives at the most, and to add to these only as they gain experience.

T. BAINBRIGGE FLETCHER,
Imperial Entomologist.

PUSA;
16th July 1914.

CONTENTS.

BEE-KEEPING.

Introductory.

Honey is so much prized that the idea of being able to keep bees and make them produce honey for the use of their owner possesses a charm in itself. Bees being very common in India, honey is obtained simply for the labour of gathering it. Therefore many think that bee-keeping is very simple work. It is simple enough if by it is meant giving shelter to the bees—because bees come and build combs wherever they get suitable shelters—and taking the honey when it is gathered. Bee-keeping as practised in India all over the Hills, is of this description. The writer has come across hill bee-keepers, some of them four-score years or more old and keeping bees from their boyhood, who do not know even the elementary things about bee life and describe the queen-bee as the *King* simply directing the colony by *his* orders and not doing anything else, and the worker bees as females who amongst other work produce young bees only once in the year. It is therefore no wonder that, though bees have been known to exist in India from time immemorial, bee-keeping has made little progress and has remained in the same condition for ages. Enormous quantities of honey are produced but as no one knows how to take out the honey from the bees' combs in a pure state, it ferments soon after being gathered and is reduced to the condition of thin jaggery or molasses. Sometimes it is worse than molasses on account of its possessing a bad odour due to fermentation. This honey is stocked for sale by grocers all over India, because there is a demand for honey for medicinial and other purposes. While holding the belief that this thin syrup sold as honey is adulterated, all purchase it because better honey is not available. As a matter of fact this honey may be pure in the sense that it has been gathered from honey bees and has not been mixed with any foreign stuff. But fermentation has produced the change and has altered the properties altogether so that it can no longer be considered as honey. This is due to its being gathered in a crude manner so that fermentation sets in within a month or two of its being gathered. Therefore it sells at a very low price in the honey season, at the rate of up to 8 lbs. per rupee or more. People purchase and eat it. Imported honey, being gathered in a proper manner, keeps for years and is sold at a rupee a pound. It must be noted here that it is not always safe to accept all imported honey as pure. Adulteration has been carried so far that even in countries like America

necessary. For the Indian bee it is essential that the frames should be placed in the hive across the entrance. For the European bees they may be placed in the same way or parallel to the entrance. Therefore in all hives we place the frames of combs across the entrance, so that the hives may be used both for the European and the Indian bee.

Further, the aim has been adaptation to prevalent Indian conditions rather than costly innovations. In many places bees are found in empty kerosene boxes and recesses in walls. Instead of discarding these kerosene boxes and wall hives, they should be converted into modern hives. Full directions are given as to how they can be thus converted.

The Bee.

The bee is a common insect, familiar to all. If we catch one and examine its body and limbs we find what is diagrammatically shown in Figure 1. The whole body is marked out into three distinct parts by means of intermediate constrictions *viz.*, head, thorax and abdomen. The head bears (1) a pair of big eyes, one on each side, (2) three small shiny eyes on the upper surface, called ocelli or simple eyes, (3) a pair of feelers called antennæ (singular, antenna), (4) a pair of jaws which can be used for cutting hard substances, (5) a tongue covered by the sheaths. By means of the tongue the bee sucks nectar from flowers. The thorax bears two pairs of wings,—one pair on each side—and three pairs of legs. The bee can both fly and walk. The abdomen bears at the hind end the sting whose acquaintance almost all have occasion to make. The bee, however, is not born as we see it. The mother bee gives birth to an egg and after the egg-stage two distinct and altogether different-looking stages have to be passed through before the bee appears as we see it.

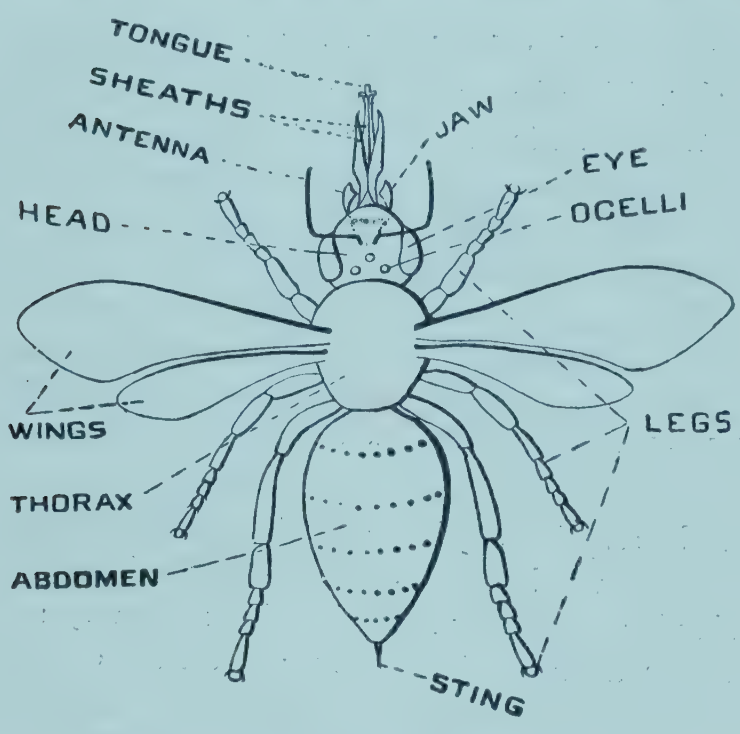

Fig. 1.—Diagrammatic illustration of a bee.

Development of the Bee.

The transformations of the bee are illustrated in Figure 2. The mother bee lays the egg (Figure 2*a*) which is a short delicate white tubular structure and slightly curved on one side. From this egg a tiny white legless wormlike grub hatches (Figure 3B). The grub feeds and grows in size (Figure 2*b*) and when fullgrown and fullfed, transforms into pupa (Figure 2*c*). The pupa is similar in appearance to the bee having developed legs, mouth-parts and all the appendages of the body. But these appendages are folded on the body and are not capable of being used. The pupa is the resting or sleeping stage and from it the active busy bee is born. The adult bee is capable of taking care of itself but in the three earlier stages of development, *i.e.*, in the egg, grub and pupa stages, it is helpless and has to remain in the comb under the care of the adult bees.

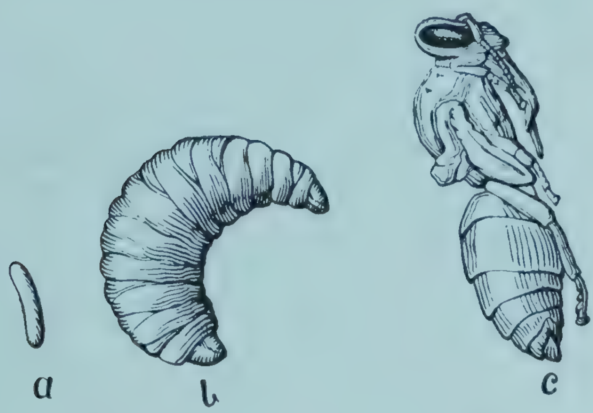

Fig. 2.—Development of the bee.
(*a*) Egg ; (*b*) Grub ; (*c*) Pupa. (All are magnified.)

Figure 3 illustrates how these stages are passed in the comb. The honey comb, as every one knows, is a double series of horizontal well-like chambers attached back to back and opening in opposite directions. Each chamber is called a cell and it is hexagonal in shape. The egg is deposited by the mother bee at the bottom of the cell, one in each, as shown in Figure 3A. The egg stands on one end. The young grub is shown at Figure 3B. It lies at the bottom of the cell in a curved posture and is provided with food by the adult bees which are therefore called nurse-bees or nurses. In the first three days of the life of the grub the food provided is a very rich nitrogenous liquid substance called " Bee-milk," believed to be secreted by the nurse-bees from some glands in their head. After this period, the food given is a sort of a paste, called " bee-bread " prepared by the nurse-bees with pollen principally, and a little honey and water. A large quantity of food is not given at a time but only so much as is required by the grub. The nurse-bees therefore have to watch the grubs constantly and this they do unceasingly. Figure 3C shows how the grub remains coiled in the cell when it is grown and ultimately stretches itself and occupies the cell lengthwise as shown in Figure 3D. When it is full grown it does not require any more food and the nurse-bees close the mouth of the cell in order to provide it with a snug closed chamber in which it may pass the resting pupal stage undisturbed. As a further protection the grub itself lines the closed cell

with a very thin layer of silk exuded from its mouth. When it has spun this silken covering the grub rests for a short time before transforming into a pupa with its head turned towards the now closed mouth of the cell. The pupa is shown at E, Figure 3. When the bee is born from the pupa, it bites away the cover of the cell, comes out and takes its place among the adults. In a bee-colony several thousand grubs are thus reared at a time and are spoken of as "brood." While the grubs are being fed they are called "unsealed" or "uncapped" brood and when their cells are closed they are called "capped" or "sealed brood." The unsealed brood requires constant attention from the nurse-bees, but all, eggs as well as both sealed and unsealed brood, have to be under the care of the adult bees for warmth. The adult bees sit upon the combs covering them and thus keeping them warm. Without this warmth the eggs do not hatch and the brood, whether sealed or unsealed, dies. Therefore it is clear that the bees in a colony will rear only as much brood as they can care for and keep warm. A populous colony rears more brood than a weaker one. Also the same colony rears more brood when the bees get and gather nectar and pollen from plants than when these substances become scarce.

It must be remembered that actual growth takes place in the grub stage when food is taken. The egg and pupa are dormant stages. The adult bee feeds in order to live but does not grow at all.

The Bee Colony.

Honey bees are social insects and live in large colonies (Figures 4 and 5). Wherever they live they build the well-known honey-comb. The chambers or cells of the comb are utilized for rearing the brood and as store-houses for honey and pollen. All the adult bees forming the colony sit in a cluster on and covering the combs and they have not got and do not require any enclosed chambers for themselves. The members making up the colony are, the mother bee or as she is called the "queen," a large number of working bees called "workers," and some male bees called "drones." Drones may or may not be present throughout the year. The queen, workers and drones undergo the same transformations in their development but are different in appearance and size. In Plate 1, figures 1, 2 and 3, show respectively the queen, the worker and the drone of the Italian (European) Bee (*Apis mellifica*), figures 4, 5 and 6 those of the Indian Bee (*Apis indica*) and figures 7, 8 and 9 those of the Little Bee (*Apis florea*). All the figures are drawn to the same scale and magnified about 2½ times the natural size. The comparative sizes of the three different varieties of bees as well as those of the queen, worker and drone

PLATE II.

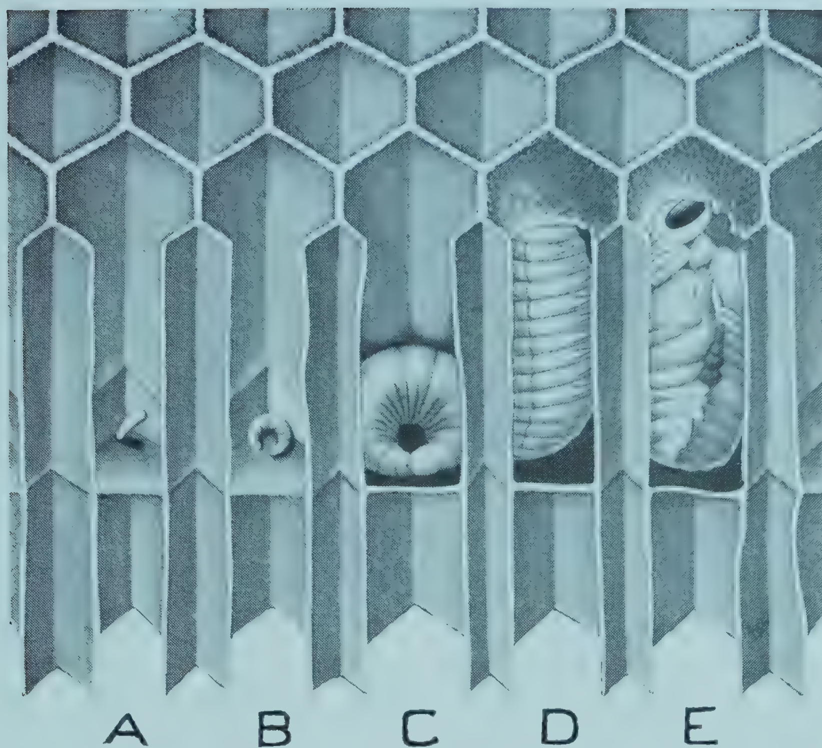

Fig. 3.—Development of the bee in the comb.

A. Egg as naturally laid at the bottom of the cell.

B. Young grub as it remains at the bottom of the cell after hatching from the egg.

C. Grown up grub as it remains coiled in the cell.

D. Full-grown grub ready to pupate in the capped cell.

E. Pupa in the cell.

Fig. 4.—A Colony of the Indian Bee (*Apis indica*).

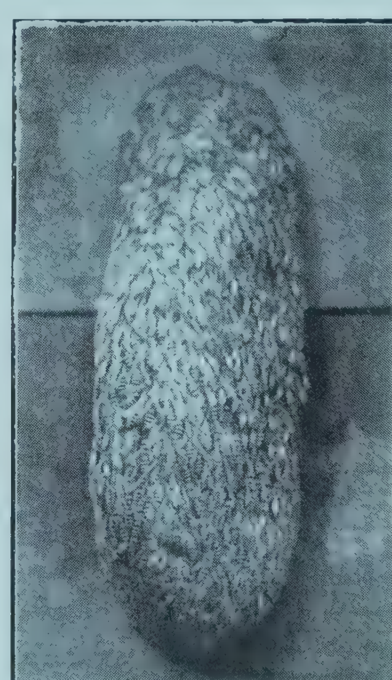

Fig. 5.—A Colony of the Little Bee (*Apis florea*).

are evident. There is a distinct differentiation of the work to be done by these different members and in order to fit them for their respective work some modifications are observed in their development.

The Queen.

In a colony there is, as a rule, only one queen. She is the mother of all the workers and drones found in the colony as well as of any queen that may be born in the colony. Her only function is to lay eggs. There is no special "royal" chamber or seat for her. She, like all the other members of the colony, sits on the combs and walks over all the parts of all the combs, and goes about depositing eggs in the cells. She thrusts her head into each cell to see if it is empty and then moves forward, thrusts the hind end of her body into it and deposits a single egg at the bottom of the cell. Her part of the work is done when she has deposited the egg, which as well as the subsequent grub and pupa are taken care of by the workers. She lays several hundred eggs every day and is capable of laying and does lay up to two thousand or more eggs daily in the height of the season. She lives for about three years. New queens are produced only when it becomes necessary to replace the reigning one. As the queen is the most important member of the colony, being the mother of all, particular care is taken of her from the beginning. The grub which will ultimately develop into a queen is fed in a specially built elongated big chamber, called a queen-cell (Figure 6), in order to provide it with a large space

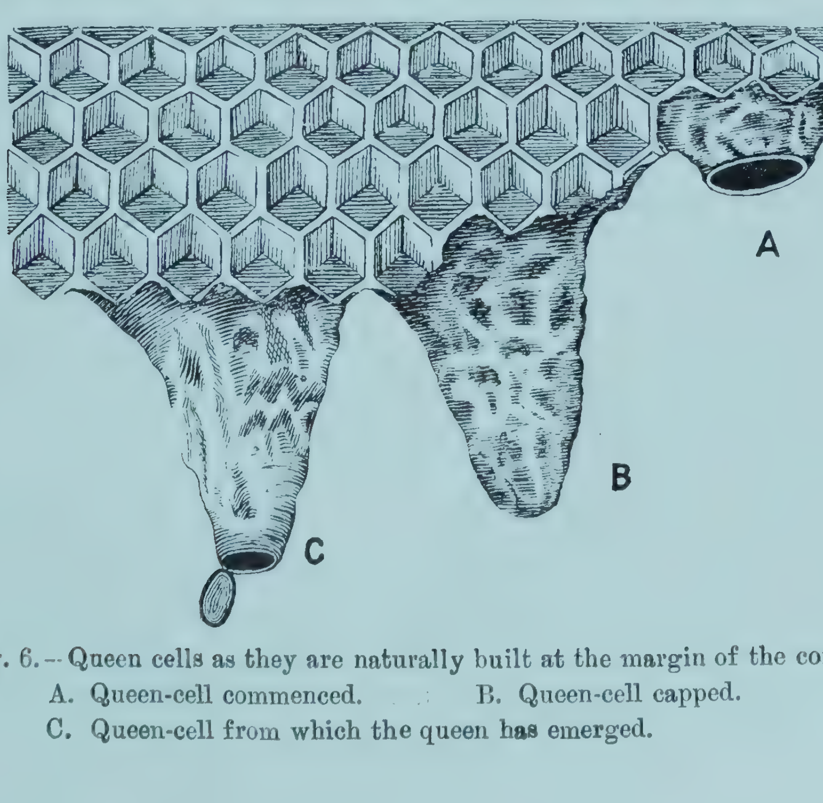

Fig. 6.—Queen cells as they are naturally built at the margin of the comb.
A. Queen-cell commenced. B. Queen-cell capped.
C. Queen-cell from which the queen has emerged.

so that its growth may take place unimpeded. When it is intended to rear a queen, such a cell is built (Figure 6A) and the reigning queen is persuaded to lay an egg in it. The egg hatches after three days. The grub is provided with a profusion of the rich nitrogenous bee-milk which, as it forms the only food of the queen grub, is also called "royal jelly." It becomes fullgrown in about 5½ days and then the queen-cell is capped as in Figure 6B. The grub transforms into a pupa and attains the adult stage in about 7 days more and comes out by opening the apical part of the queen-cell like a hinged lid as shown at Figure 6C. After this the queen-cell is demolished by the bees.

When the queen is about five days old she goes out of the hive in the middle of the day and flies out into the open air in order to meet a drone. She may be surrounded by hundreds of drones in the hive but never mates inside the hive. Probably this is the provision in nature to prevent in-breeding. The drones too fly in the middle of the day and when the virgin queen comes out of the hive and flies, they are attracted to her probably by a particular smell she emits. She mates with one drone who may overtake her in her flight. The drone dies soon after mating has taken place and the queen returns to the hive and then begins to lay eggs and does not usually leave the hive afterwards. The queen may not succeed in meeting with a drone on the first day and in that case will go out every day until she finds one. She will thus go out only until she is about three weeks old, after which she does not go out even though she has not succeeded in mating; she is then destined to remain a virgin.

Whether the queen has succeeded in finding a mate or not is a matter of vital concern to the hive. If she has been fertilized by a drone she will be able to give birth to queens, workers and drones. But if she has not been fertilized, she gives birth to drones only and this phenomenon is known as Agamogenesis, *i.e.*, production of offspring without coming in contact with a male. The properly fecundated queen is able to produce all kinds of bees, *viz.*, queens, workers, and drones for the following reason. When she mates with a drone the male sperm or seminal fluid is collected in a special receptacle, which has an opening into the passage through which eggs have to pass when being deposited and each egg, as it passes out to be laid, receives a minute portion of the seminal fluid from the seminal sac and is thus impregnated. The queen has the power of closing or opening the outlet of the seminal receptacle at will and thus of allowing or not allowing any egg to be impregnated. Therefore a fertilized queen has the power of laying two kinds of eggs, impregnated or unimpregnated. From unimpregnated eggs drones are born and from impregnated ones queens and workers are born. The difference between a queen and a

worker is only one of degree of development. Both are of the female sex; the queen is a fully developed female having all her parts and organs fully developed; the worker is an undeveloped female, her organs not developing on account of the stinted nature of the food given to her while she is in the grub stage. Therefore we see that the fertilized queen lays male eggs from which drones or male bees are born and female eggs from which female bees, *viz.*, workers or queens are born. The sex of the egg is determined, before it is laid, by impregnation or otherwise with the seminal fluid. Therefore it is clear that when the contents of the seminal sac are exhausted, the queen will lay only unimpregnated eggs from which drones only will be born. This is what actually happens. When the queen is old she produces many drones, as all the eggs are not impregnated on account of the lessening of the fertilizing fluid, and ultimately produces nothing but drones when the fluid is entirely used up. Also when she is not properly fertilized, she breeds both workers and drones in the beginning as long as the seminal fluid lasts and then begins to breed drones only even in the prime of her life.

The Worker.

As will appear from the figures in Plate 1, the worker-bee is smaller in size than the queen or the drone, but more agile and active than either. The workers form the main population of the colony and in a fairly strong colony ought to number not less than 20,000 and in a good strong one there may be forty, fifty or sixty thousand or even more workers.

The worker bees are reared in the ordinary cells of the comb, Figure No. 3 showing the various stages of development. The ordinary cells of the honey-comb are for this reason called "worker cells." As already explained the queen lays one impregnated egg in each cell. The egg hatches after three days and the grub is fed by the nurse-bees for about six days. For the first three days the food given to it is the same royal jelly as given to a queen grub and then it is bee-bread. We have seen that the queen-grub is fed with royal jelly all along. This difference of food brings about the difference between a queen and a worker-bee. The rich royal jelly enables the queen to attain full development and she becomes a perfect female. The less nutritious bee-bread does not enable the worker to be fully developed and she remains an imperfectly developed female. After six days of feeding the cell is capped and the grub pupates inside and comes out as the adult worker-bee in eleven days more.

As their name implies, it is the worker-bees which do every kind of work that has to be done in a colony.

(1) They build comb. Combs are built with wax and not with pollen as supposed by many. This wax the workers secret efrom their own body through certain parts situated on their lower surface and then build the comb by moulding the wax with their mouths.

(2) They rear the brood, *i.e.*, take care in the developmental stages of all the bees which are born in the colony. They secrete royal jelly from the glands in their head and prepare bee-bread and distribute these foods to the grubs.

(3) They keep up the warmth of the hive.

(4) When the hive becomes heated they fan out the hot air with their wings.

(5) They guard the colony against enemies.

(6) They take care of the store, *i.e.*, honey. When the honey is freshly gathered from flowers it contains a good deal of moisture. The warmth of the hive evaporates this moisture and when it has been evaporated to a point which just keeps the honey in the fluid state, the honey is said to be ripe and then the bees close the cells containing honey with a layer of wax. It is then spoken of as " sealed " or " capped " honey.

(7) They keep the hive clean, carefully throwing out dirt and debris and dead bees.

(8) They take care of the queen, attending on her in her perambulation over the combs and feeding her with royal jelly in order to keep up her strength and vigour in her exhausting work of depositing thousands of eggs.

(9) They gather honey, pollen and water for the use of the colony as food and a dark-coloured gum called bee-glue or propolis with which they stop cracks and crevices in the hive. Honey is the principal food of the adult bees and pollen that of the developing grubs. The honey and pollen gathered by the bees is spoken of as " bee-forage ."

Items (1) to (8) constitute work in the hive and (9) that outside the hive. Here too we find a differentiation of work though not hard and fast, the older workers doing the outside work being styled " foragers " and the younger workers doing the work inside the hive, being styled " nurse-bees " or " nurses." This differentiation becomes rather necessary, as those workers which are about two weeks or so old are not capable of secreting, at least so well and in as large quantities as young workers, the royal jelly so essentially necessary for rearing brood. The young workers work as nurses for about two weeks after which they begin to work as foragers, but may begin earlier when there is press of work. Similarly foragers too can do, if necessary, at least a part of the work inside the hive.

The above constitute the routine work of the hive. As will appear later on the workers do other work of a very high order of intelligence or instinct or whatever we may call it, at the time of replacing an old or dead queen or swarming.

It may be asked how long the workers live when they have so much work to do. In busy seasons when an excessive amount of brood-rearing and foraging has to be done, they do not live for more than five to six weeks. As will appear later on, the greater part of the year is not a busy season for the bees, and at this time the workers live for about three months. In countries with severe winters the bees hibernate in the cold weather, no brood-rearing or foraging being done. The workers live through the hibernation period in those countries. In India the bees do not hibernate, at least in the Plains.

It is clear that with such a short life for workers, in order that the colony may go on, new workers must always be born to take the place of those which die. This actually takes place. New eggs are being laid, new worker brood reared and new workers born every day in the bee-colony. Queens and drones are reared at particular seasons in the year. Therefore by "brood" is ordinarily meant worker brood, drone brood being spoken of specifically as "drone brood."

The Drone.

As will appear from Plate 1, the drone (the male bee) is bigger than the worker and as bulky as, if not bulkier than, the queen. As already explained drones are born from unimpregnated eggs. They are reared in cells similar to worker cells but slightly larger in size in order to accommodate the larger-bodied grubs, these cells being therefore called "drone-cells." Figure 25 shows the worker, drone and queen cells of three kinds of honey bees. Like the ordinary worker-cells, the drone-cells are built in the comb and usually on its lower part and are allowed to remain permanently. Drones may be reared in ordinary worker-cells but then they are dwarfed in size. The egg hatches in three days. The grub is fed with royal jelly for the first three days and then for about four days more, with bee-bread mixed with a little royal jelly. Therefore the food given to the drone grub is richer than that given to the worker grub in order that all his organs may fully develop and he may be a perfectly developed male. The drones are born and come out from the cells after thirteen days from the time they are capped.

The only function of the drone in the colony is to impregnate virgin queens and how this happens we have seen already. Therefore drones appear in the colony only when their services may be required, *i.e.*, when

new queens may be produced and require to be fertilized. Consequently in a normal colony drones are not found throughout the year. They help in no work of the colony, but on the other hand eat the honey gathered by the workers, being incapable of gathering even their own food from outside. Therefore the bees tolerate the presence of drones in the colony only whilst they are getting honey and pollen from plants. When the food supply from outside fails, the drones are killed or driven out of the hive after their wings have been maimed, so that they cannot fly back into the hive, and perish. They are not allowed to live the normal period of their life which is probably about two months.

Distinctions between the different members of the Colony.

In appearance and size there is no difference in the eggs. In the grub stage there is no difference in appearance but queen and drone grubs are bigger in size than worker grubs. In the pupa stage the male (drone) and female (queen and worker) bees can be easily distinguished by examining the eyes. In the drone pupa (Figure 7*b*) the eyes meet over the head. In the queen and worker pupa (Figure 7*a*) the eyes are far apart. Without taking out the pupa from the closed cells, it can be easily made out whether there is a drone pupa or a worker pupa inside. The worker pupa is capped with a flat capping and the drone pupa with a convex capping as shown in Figures 8 and 24. Stored honey is also capped in the same way as the worker pupa but the capping of honey has a shiny appearance; the capping of worker brood has a dull dry appearance.

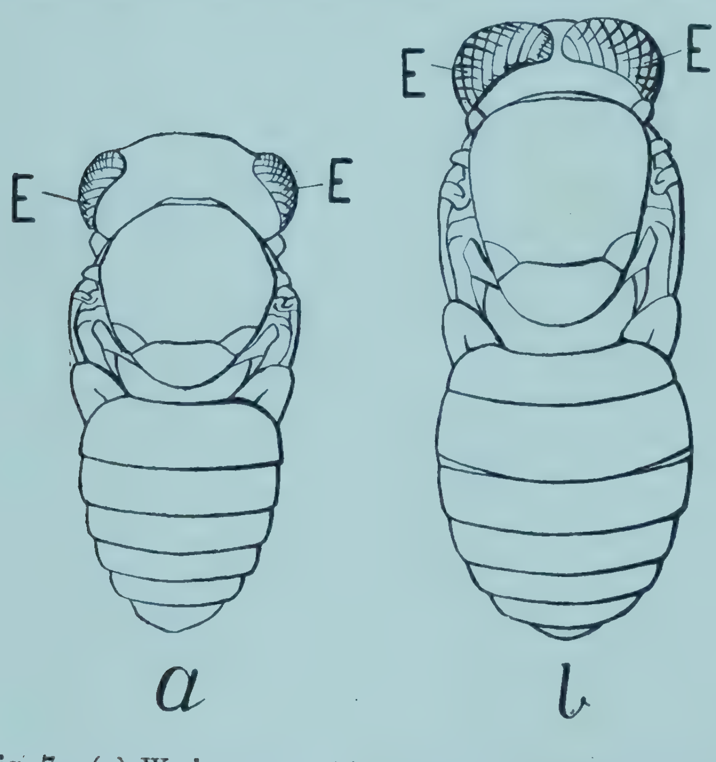

Fig. 7.—(*a*) Worker pupa; (*b*) Drone pupa; both viewed from back. (*E*) Eyes.

The capping of the drone brood of the Indian Bee is not only convex but somewhat pyramidal or conical, the top of the cone having a dark spot. There is a minute hole in the middle of this spot for ventilation. In the

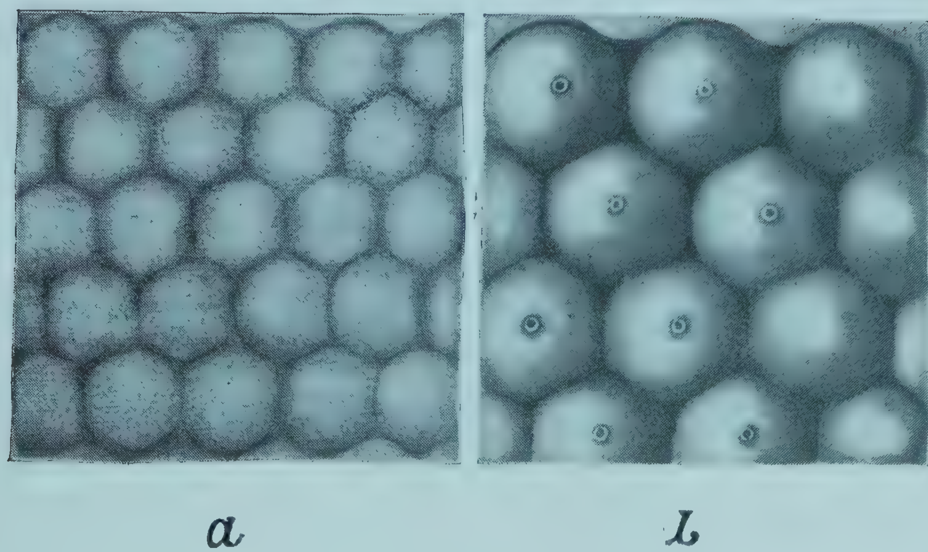

Fig. 8.—(*a*) Capping of worker-cells.
(*b*) Capping of drone-cells ; the characteristic capping of drone-cells of the Indian Bee is shown towards the left side. (Also see Fig. 24.)

season of honeyflow, this conical appearance may not be apparent in all cases as the cone is sometimes covered with a layer of wax. But the convexity is not hidden. When the layer of wax is removed the cone with the black spot and hole appears. In the adult stage the distinctions between queen, workers and drones are quite clear (see Plate I). The eyes of the drone meet over the head, those of the queen and worker are far apart as shown in Figure 9. The workers have to gather nectar and pollen from flowers ; therefore the limbs used in gathering these substances are modified. They suck out the nectar from flowers with their tongue. Their tongue is therefore more developed and longer than that of either the queen or the drone. The pollen is gathered and carried home on the thighs of their hind legs which are therefore modified and adapted for this purpose and are slightly different in structure from the hind legs of the queen or the drone. Figure 10 shows the hind leg of a worker and also the part where pollen is carried, this part being known as the " pollen basket. " The queen and drone have no pollen basket. The workers have to secrete wax with which to build the comb. The wax is secreted through four pairs of structures, called " waxplates " on the under surface

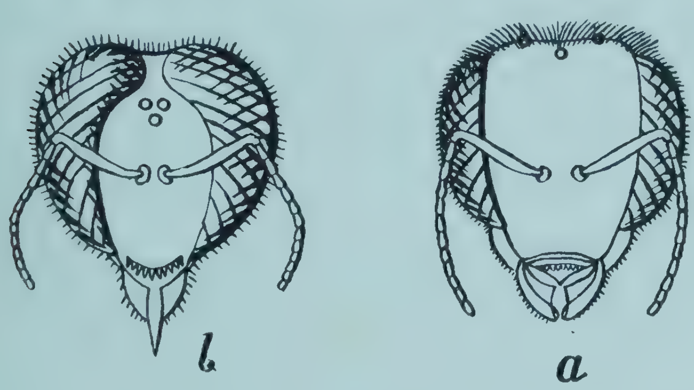

Fig. 9.—Front view of head of (*a*) worker and (*b*) drone.

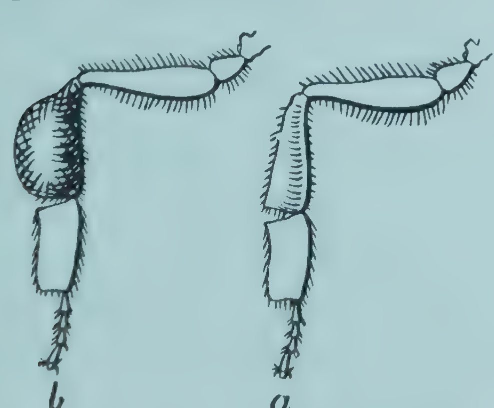

Fig. 10.—(*a*) Hind leg of a worker bee.
(*b*) The same with a mass of pollen on it.

of their abdomen, shown in Figure 11. The queen and the drone possess no

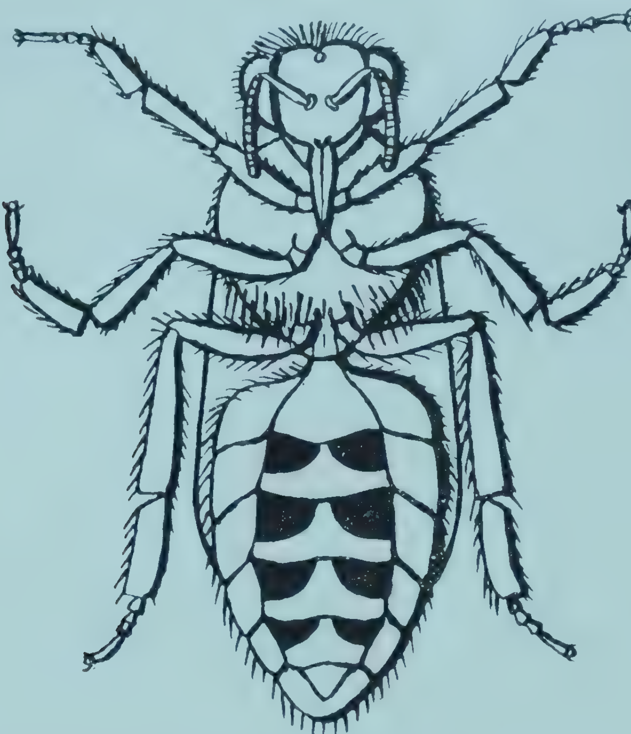

Fig. 11.—A worker bee (magnified) turned on the back to show the wax-plates ; the shaded parts are the wax-plates.

wax-plates. The worker has in the sting a powerful weapon of offence and defence. In the queen the sting is slightly modified and is used as the egg-placer or ovipositor as it is called, the egg as it comes out of the abdomen being protruded out through a hole in the ovipositor and placed by it in the proper situation at the bottom of the cell. The drone possesses no sting.

Relative Importance of the Different Members of the Colony.

We can now understand the relative importance of the diffierent members forming the bee colony. A normal colony must have a properly fertilized queen which will lay a large number of eggs every day and there must be a large body of workers able to collect honey, pollen and water from outside, to rear the brood and to perform the various other kinds of work necessary for the well-being of the colony Provided these members are present in an efficient condition drones are not necessary. Of the essential members again the queen alone cannot form or even start a colony, being incapable of secreting wax, building comb, collecting food from outside and rearing brood. The body of workers alone without the queen may continue the colony only as long as they live and the colony will be extinct in the course of about three months when all of them have died off.

A normal colony begins to weaken when the queen, through old age, fails to produce enough impregnated eggs sufficient to replace the workers which die and it begins to dwindle from the time when the queen fails to produce any impregnated eggs on account of the exhaustion of the male sperm in the seminal receptacle and when she dies. In nature the bees (by which the worker-bees only should be understood) foresee the danger and hasten to rear a new queen in time, *i.e.*, before the reigning queen is too old to lay impregnated eggs and before the colony becomes too weak. They build queen-cells and persuade the queen to lay eggs in them and rear several queens although they require only one, in order to guard against emergencies. Before the queens are reared a provision is always made for their fertilization, some drones being reared beforehand so that when the new queens emerge there are drones present to fertilize them. When a young queen is obtained the old queen is killed. When however the queen dies suddenly through some accident the bees rear queens from some of the impregnated eggs laid by the late queen in the worker-cells, the worker-cells round these eggs being demolished and queen-cells built in their place. These new queens take their chance of being fertilized by any drones which may happen to be present in the same or other colonies. If no fertilized queen is obtained the colony is doomed to extinction. The unfertilized queen may live and lay eggs ; but as we know, only drones are born from these eggs. No more workers being born to replace those which die, the colony becomes extinct when all the workers are dead.

When there is no queen in the colony and all attempts to secure one are unsuccessful, one of the workers takes the place of the queen and begins to lay eggs. The worker-bee, as we already know, is an undeveloped female and occasionally she is capable of laying eggs. Such a worker is known as " fertile-worker. " The eggs laid by her, however, not being fertilized, give rise to drones only. Therefore the colony is not saved and becomes extinct in time.

It is more often than not that the colonies succeed in re-queening themselves and if they are successful they may go on for years, colonies being known which are forty years old or even older. But the age of the colony must not be confused with that of the members forming it.

How the Bees recognize the Members of their own Colony.

Every colony has a distinctive smell and the bees recognize the members of their own colony by this smell. If a bee belonging to a different colony tries to enter the hive of a colony, the guard bees promptly

attack it at the entrance and drive or kill it. If bees are separated from a colony and kept separate for some time (several hours are enough) they lose the characteristic smell of the colony and will be treated as foreigners when given back to the colony after this period.

Honey and Honey-flow.

Bees do not make honey. Plants secrete a sugary liquid called nectar in the flowers. Bees collect this nectar, sucking it up with their tongue into a pouch in their stomach called the " honey-sac " and then on arrival at the hive disgorging and storing it in the cells of the combs. Certain chemical changes take place in the nectar while it remains in the honey-sac of the bee, converting it into the honey we get. All plants do not yield nectar and those which do, secrete it in minute quantities which, however, vary in different plants. It is not at all times of the year that bees gather honey. Usually there is a particular season when plants secrete large quantities of nectar, it being known as the season of honey-flow. At Pusa and probably everywhere in the Plains the principal honey-flow occurs in spring and early summer from about the end of January to about the end of April, there being a minor unimportant flow in October-November. In the Hills (*e.g.*, Shillong, Darjiling, Nainital, etc.) the principal honey-flow occurs in October-November, and a secondary flow in March-April. It is only in the seasons of honey-flow that the bees get honey to store up. There are periods in the year, for instance, the rains, when very little honey is available. Bees gather honey for their own use as food. They gather much more than they require and in fact they continue gathering as long as nectar is available, as long as they are able to gather it and as long as there is accommodation for it in the combs. We have seen that it is the worker bees which gather honey. Therefore it is evident that the greater the number of workers in a colony the more honey they will gather and store. As it is only in the seasons of honey-flow that plenty of honey and pollen is available, brood-rearing is carried on on a large scale at is time. The population of the colony therefore increases rapidly and it is then that the phenomenon, known as swarming (see page 20) takes place.

Bees and Plants.

In order to be able to understand the relation between bees and plants, it is necessary to know something about how the plants reproduce themselves. The reproduction of plants takes place in one of the following ways :—

(1) A part of the parent plant, root, stem or leaf, is capable

of giving rise to a new plant. For instance, bulbs of onion and garlic, tubers of potato, rhizomes or rootstalks of arum, turmeric and ginger give rise to new plants. All are familiar with growing roses, sugarcane and sweet potato from cuttings of the stem. New plants grow from the leaves of Bryophyllum. This kind of reproduction is known as vegetative.

(2) In ferns etc., we find special cells are produced either on the back of the leaves or in their axils and these special cells are by themselves capable of giving rise to new plants. This is known as a sexual reproduction.

(3) The third form is by the production of seeds which, when planted in ground, give rise to new individuals. Such plants produce two kinds of special cells, *viz.*, female cells or ovules (future seeds) in the female organ, the pistil, and male cells or pollen on the male organs, the stamens.

In order to enable the ovules to develop into seeds it is essentially necessary that the contents of the pollen should unite with those of the ovule. The ovule is thus fertilized. For this purpose the pollen must be conveyed to a particular receptive part of the pistil. This is called pollination and fertilization of the ovule follows pollination. The male and female organs, that is, the stamens and pistils respectively, are in most cases located in the same flower which is therefore called bi-sexual. Pollination with pollen of the same flower is called self-pollination or self-fertilization, and that with the pollen of other flowers, cross-pollination or cross-fertilization. Cross-pollination yields more and better seeds than self-pollination. In some cases self-pollination fails to fertilize the ovule and in some cases again it is found to be distinctly injurious. Therefore in nature there are various devices to ensure cross-pollination. Thus a cucumber plant bears two kinds of flowers, some male and others female. The papaya bears either male or female flowers exclusively. In many cases although the flowers may be bi-sexual, having both the organs, self-pollination is prevented by the two organs maturing at different times or by the organs being of such different lengths as to preclude self-pollination or by other mechanisms preventing pollen from falling on the pistils of the same flower. In all such cases pollen from different flowers or different plants must be conveyed through some external agency to the female flowers for the necessary fertilization of ovules, so that seeds may be produced and the species continued.

Pollen may be carried from flower to flower by wind, water, insects or other animals and the plants are classed according to these pollinating

agents as anemophilous, hydrophilous, entomophilous or zoophilous, respectively. Of the plants with sexual reproduction a large number is entomophilous, *i.e.*, pollination or rather cross-pollination in them is effected by insects among which honey-bees are included. These plants usually have large, coloured and showy flowers not infrequently possessing characteristic odours and as a further attraction to their insect visitors produce nectar and that too in such a situation in the flower as will ensure the removal of pollen and also the application of some pollen to the pistils by the insects in their search for the nectar. As the insects visit different flowers they distribute the pollen of some flowers to others. The parts of the flowers are sometimes modified to adapt them to the habit of their insect visitors and sometimes the adaptation goes so far as to render the plants capable of being visited by one particular class of insects and by no others. Thus in Australia it was not possible to obtain seed from red clover until the bumble bees were introduced. We see the mutual dependence of plants and insects. The bees, with which we are concerned, depend on the plants for nectar and pollen and the plants too depend on the bees for the necessary fertilization of their seeds. This fact is made of practical use by growers of cucumbers in green-houses in Massachusetts, United States of America. When the cucumber vines are in bloom they introduce and keep in green-houses colonies of bees for getting the crop set, and in this way utilize a large number of colonies. It is reported that in one year 118 growers utilized 944 colonies of bees for this purpose. The colonies thus kept in green-houses usually die as they do not get enough food and fresh colonies have to be purchased and introduced every year. It must be remembered that colonies of bees are always available for sale there, bee-keeping being an established industry.

Pasturage.

Plants affording pollen and honey to bees are spoken of as bee-pasturage. We have seen that all members of the vegetable kingdom do not yield nectar and pollen to bees and also all of the flowering plants may not do the same. For instance there may be whole fields of sann-hemp in full bloom but the honey-bees do not get a single drop of nectar from them. The mechanism of these flowers precludes the true honey-bees, while allowing bumble bees to gather a harvest easily. For similar reasons, all flowers cannot be visited by all of the different kinds of honey-bees. The flowers may be so small that only the smaller bees can thrust their tongue into them to suck out the nectar. Or the nectar may be situated at such a depth inside the flower that only those bees which possess a long tongue can reach it. It is very commonly found that certain flowers are visited by

the Little Bee only and by no others. On the other hand some flowers will be found to be visited by all kinds of honey-bees. What constitutes bee-pasturage in a locality has to be found out by actually observing the flowers visited by the honey-bees. Very little work has been done in this direction in India.

Different plants yield different quantities as well as different qualities of nectar. The same plants may vary in these respects in different countries according to the soil and climate. Plants are known which yield abundant nectar in one country but hardly any in another. Similarly the same plants in a particular locality may yield enough nectar in one year but much less in another year according to the change in the climatic conditions. Warm dry atmosphere helps secretion of nectar, a cold wet atmosphere retarding it. Also more nectar is secreted in the morning and evening than in the middle of the day.

It does not pay to cultivate any plants solely for the bees. Plants, which are useful and at the same time yield abundant nectar, may be grown. Or, to put it in a proper way, those who grow such plants will find it profitable to keep bees, as in addition to the outturn of the crop itself, they will have a yield of honey. This practice is often followed in advanced countries. Such crops are usually those which grow densely in a small place and put forth an abundance of flowers. Clover and alfalfa or lucerne, grown for fodder, may be named. An acre of alfalfa in some countries is said to yield as much as 60 lbs. of honey or as the farmers put it "a can of honey (60 lbs.) to the ton of hay." In the same way mustard and sesamum crops in India yield abundant honey.

But the question becomes different when abundant waste lands are available in the neighbourhood where seeds of wild nectar-yielding plants may be grown for the sowing at no great or nominal expense. As it is, however, in India enormous quantities of nectar which is produced by plants both wild and ordinarily cultivated, are wasted because there are not enough and good bees to gather it.

Bees gather honey principally from wild plants, and go to a distance of as far as two to three miles in all directions. But of course the nearer the pasturage the better, as the bees can gather and store more honey when the distance they have to cover in coming and going is small. A few flowering plants cultivated in a garden are no help to them. Usually the flowers cultivated in the garden are mostly made double by cultivation and produce no seed. Therefore they have no necessity for the service of the bees and produce no nectar for them.

Then it has been calculated that in order to obtain about $\frac{1}{22}$ ounce of honey the bees have to visit at least 2,129 flowers of *Rhododendron hirsutum* and 5,530 of sainfoin (*Onobrychis sativa*). From this one can imagine what

a large number of flowers are required to secrete nectar and also what a large number of bees are required to gather the nectar in order to have surplus honey. It is evident that though there may be some flowers always available, it does not follow that the bees will gather and store honey. For this purpose there must be abundant pasturage which must put forth an abundance of bloom. This does not always happen and when it happens we have the honey-flow. From the point of view of a practical bee-keeper, a knowledge of the pasturage of his locality and the time when it comes into bloom is very necessary. He can then so regulate his bees as to make the most of the honey-flow when it comes.

Honey-dew honey.

Sometimes bees gather the sugary secretion of plant lice (Aphides) and other insects, known as insect honey-dew, and also a similar secretion of certain plants from extra-floral parts, known as plant honey-dew. This is known as honey-dew honey and is of course much inferior to the floral nectar. So long, however, as nectar is available honey-dew is not collected. In India so far as is known bees get nectar when the honey-dew secreting insects occur and bees will not ordinarily be found collecting honey-dew.

Swarming.

In the case of bees a colony may breed a large number of individuals but as the colony is nothing more than a single family, there is properly speaking no multiplication unless there be an increase in the number of colonies. The bees bring about this increase by what is known as swarming. In the season of plenty, *i.e.*, the season of the honey-flow, when the colony becomes very populous, swarming takes place in the following manner. A number of drones are reared and when the drones begin to fly some queen-cells are built and queens reared. Soon after the first of the queen-cells is capped, all on a sudden in the middle of a bright day a large number of workers, about half of the number present or more, with some drones, fly out of the hive, headed by the reigning queen and go to a new place to establish a new colony. This is called swarming. The flight of a swarm with whirling movements in the air and with a loud humming noise, is a common sight in India in spring and the beginning of the hot weather. The swarm builds combs in the new quarters and is soon established as a normal colony. In the parent colony a new queen is born and fertilized by one of the drones who are already there and takes the place of the old queen. After the first queen emerges the other queen-cells are demolished and their occupants killed. But in some cases the bees in the parent colony wish to send out a second swarm and do not destroy the other queen-cells. The

second swarm is sent out usually in about a week after the issue of the first swarm and it is headed by the first-born young queen before she is fertilized. She is fertilized in the new quarters. Similarly several successive swarms may be sent out until the population in the parent colony becomes very reduced. Each swarm goes and selects new quarters for itself.

Migration.

Sometimes bees naturally migrate from place to place. The phenomenon is very common in India. The entire colony leaves the habitation with the combs and settles in another part of the country in one season, returning again in another season. Thus colonies migrate from the Plains to the Hills in autumn and return to the Plains about the middle of the winter. The causes inducing migration are probably changes in the climate but more probably dearth and availability of food supply.

Enemies and Diseases of Bees.

The honey-bees in India have many natural enemies. Three kinds of birds, two green ones known as Bee-eaters (*Merops viridis* and *M. philippinus*—Fig. 12) and the third a black bird with a forked tail, known as the

Fig. 12.—The Bee-eater.

King-crow (*Dicrurus ater*—Fig. 13), catch bees on the wing and eat them.

Fig. 13.—The King Crow.

King-crows are not habitual bee-eaters, but some of them develop a strong liking for bees occasionally. Five kinds of predaceous wasps (*Vespa orientalis*, Fig. 14, and *V. cincta* in the Plains and *V. auraria*, Fig. 15,

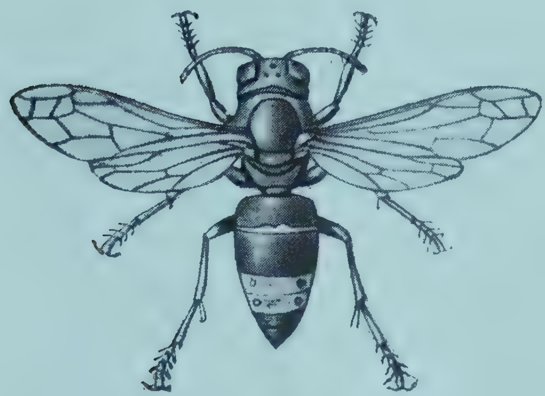

Fig. 14.—The yellow banded brown wasp (*Vespa orientalis*).

Fig. 15.—The golden wasp (*Vespa auraria*).

V. ducalis and *V. magnifica,* Fig. 16, in the Hills) have been discovered to

Fig. 16.—The large black wasp (*Vespa magnifica*).

come, sometimes in large numbers, hover near the hive and catch and carry off bees both on the wing and sitting near the entrance of the hive. One Robber fly (Asilidæ) has been observed to catch bees on the wing and eat them. House and tree lizards, centipedes, spiders, frogs, mice and several kinds of predaceous ants destroy bees. One kind of Ant (*Dorylus orientalis*—Fig. 17) sometimes gets scent of hives and attacks the combs for grubs and pupæ in such large numbers that the bees are compelled to desert the hives.

Fig. 17.—*Dorylus orientalis*; the small figure shows the natural size.

Fig 18.—The Death's Head Moth, *Acherontia styx*.

Several kinds of ants attack the hives for honey. There is one big moth (The Death's Head Moth, *Acherontia styx,* Fig. 18) which enters hives at night and drinks honey. The worst enemy of the bees in India and specially in the Plains is the Wax Moth (*Galleria mellonella*) of which an account has been published in the *Agricultural Journal of India,* Vol. VI, No. 4. Its life-history is illustrated in Plate III. The moth enters hives at night and lays eggs on the combs. The caterpillars which hatch out of these eggs tunnel the combs forming silken galleries through them (Fig. 19). They eat the combs and fill them with a profuse amount of white silk and black pellets of excreta. Ultimately in place of the combs nothing but a mass of silk and excreta is found. The bees are compelled to desert the hives. The caterpillars pupate inside the comb or in corners of the hive and ultimately come out as moths. In other countries bad and infectious diseases are known which affect the brood and also diseases affecting the adult bees. So far no such disease has been noticed in India and it is to be hoped that they will not be introduced.

The Indigenous Bees.

In India three or rather four kinds of honey-bees are found.

(1) One is the Rock Bee (*Apis dorsata*) the worker of which is illustrated at figure 10, Plate I. It will appear that the worker of the Rock Bee is as big as the queen of the European Bee (*Apis mellifica*). The colonies of these bees build a single huge comb on the face of rocks, on branches of big trees and sometimes on walls of buildings, the comb measuring up to five feet across its face, and being always built in an open place. The bees are very good honey-gatherers and from a single comb of the Rock Bee up to sixty pounds of honey is said to be obtained. But they are very ferocious and do not brook disturbance. Their sting is very painful and several cases of human beings and even big animals such as elephants being stung to death by these bees, are on record. When enraged they pursue their victims for miles. A man cannot escape from them even when he dives in water, as they hover about the place and sting him when he pushes his head out for breath. These bees are known to migrate from place to place. Wild tribes collect their combs by burning away the bees usually at night, some making it a profession to collect their combs. The honey is squeezed out and the comb is melted into wax, each comb on account of its large size yielding a large quantity. The bees-wax exported out of India and running up to the value of more than seven lakhs of rupees in a year is principally obtained from the combs of the Rock Bee. The Forest Department of India realizes a large revenue annually by leasing the right to collect these combs from Forest Areas.

EXPLANATION OF PLATE III.

Wax-moth. (*Galleria mellonella*, **Linn.**)

Fig. 1.—Piece of comb, showing Eggs, Caterpillar and Moth in resting position. Natural size.

" 2.—Caterpillar (full-grown).

" 3.—Cocoon.

" 4.—Pupa.

" 5.—Male moth.

" 6.—Female moth.

" 7.—Cluster of eggs (greatly magnified).

(The natural sizes of figures 2 to 6 are indicated by the hairlines shown alongside each.)

PLATE III.

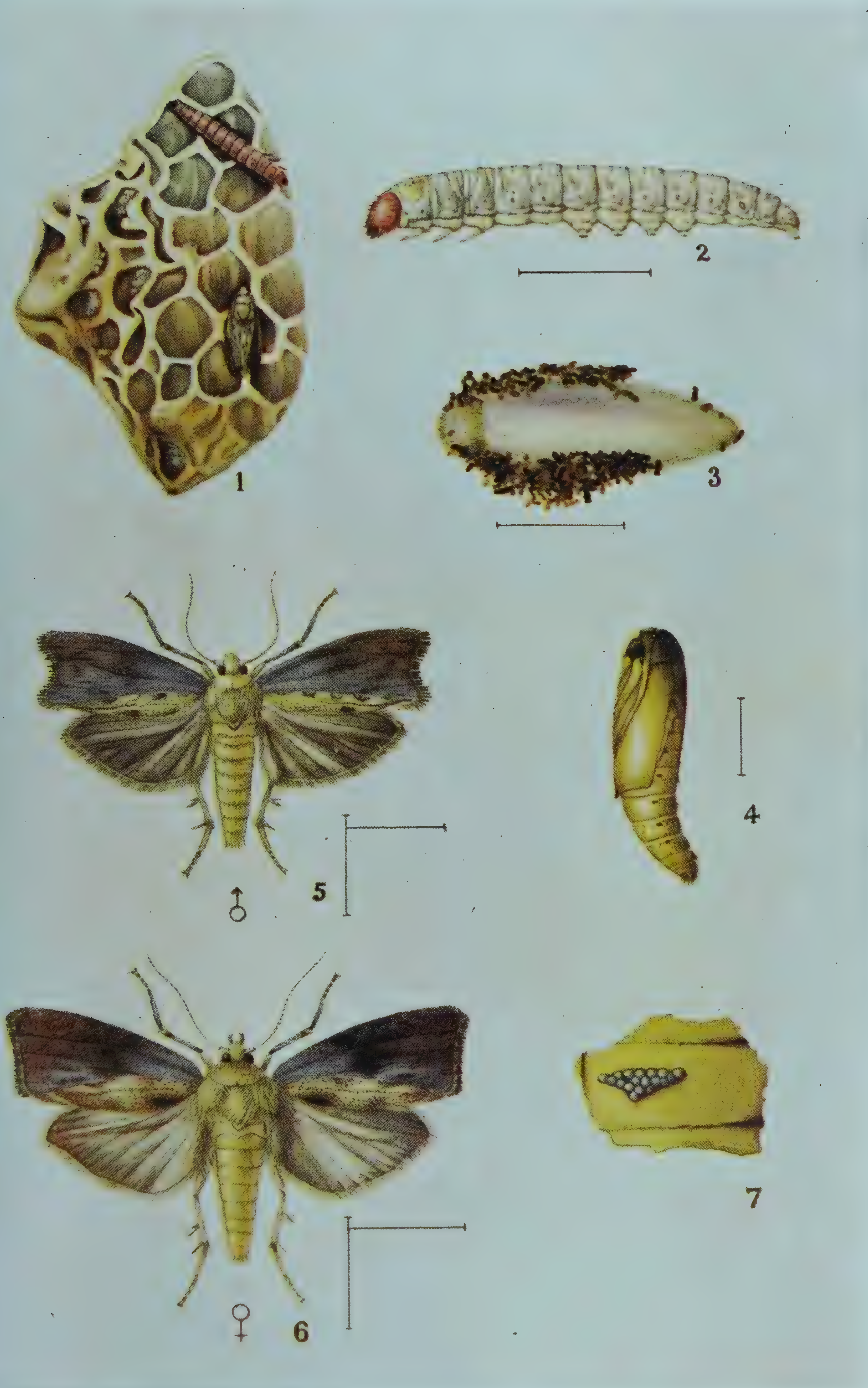

PLATE IV.

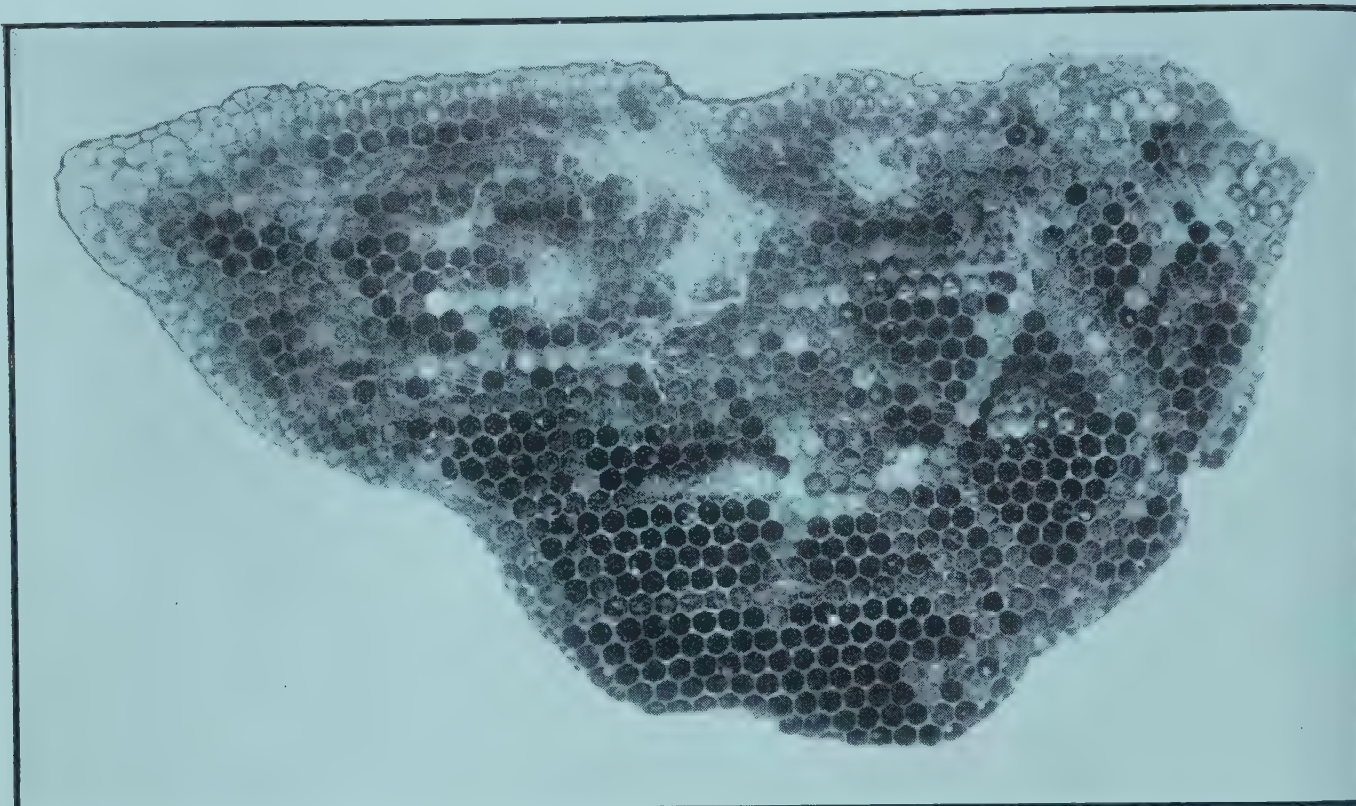

Fig. 19.—A piece of comb attacked by the Wax Moth (*Galleria mellonella*) caterpillars. The galleries of silk and the thin net-like silken covering of the mouths of cells are quite clear. At the upper part at about the middle a thick webbing of white silk has been formed.

Fig. 20.—Combs as built in nature by the Indian Bee.

(2) The second is the Indian Bee (*Apis indica*). Its queen, worker and drone are painted in Plate I, figures 4, 5 and 6 respectively. They are smaller than those of the European Bee (*Apis mellifica*). The colonies of this bee always live in closed covered places, *e.g.*, cavities in tree trunks or under the ground and in rocks or sometimes in walls. The same habit sometimes leads them to build combs in unused boxes or packing cases. At times they build inside rooms in recesses in walls or windows which are kept shut. They always build several combs side by side and parallel to each other as shown in Figure 20. According to the locality this bee shows a little variation. Thus the variety found in the Hills is slightly bigger and much darker than that found in the Plains. It is not as good a honey-gatherer as the Rock Bee or the European Bee. The maximum quantity of honey obtained from a single colony of this bee in the Plains is about seven pounds when the colony is very big or a little more in the Hills. An average quantity is about six pounds annually. The Plains variety is more irritable and more prone to stinging than the Hill variety. These bees are very prone to swarming and are found to migrate as well to some extent. The Hill varieties, however, show a less propensity to do either. They cannot defend themselves againt enemies so well as the Italian Bees and the Wax Moth plays havoc among them.

(3) The third is what may appropriately be called the Little Bee (*Apis florea*). Figures 7, 8 and 9 in Plate I show its queen, worker and drone respectively. Its worker is much smaller than that of the Indian Bee. Compared with the worker, the queen and the drone are very big but smaller than the queen and drone of the Indian Bee. The colonies of this bee build a single comb which is usually not larger than the outstretched palm of the hand but attains to a much larger size occasionally. The comb is usually built in bushes as shown in Figures 21 and 22 and hung on some branches. Frequently, however, the bees are found to build under eaves of huts and cornices of buildings and walls, in ventilator holes of houses and behind doors and windows. In the last named situations the comb is built parallel to the wall in such a way that it does not interfere with their opening and closing. Figures 23 and 24 show a comb built at the end of a log of wood in a fuel stack. The bees are not so prone to sting and have therefore been styled "stingless" by several writers. Actually they do sting and cause swelling though the injury is not so painful as that caused by the bigger bees. They gather very small quantities of honey, a single comb yielding only a few ounces.

(4) The fourth is a small bee, smaller than the Little Bee. It is called the Dammar Bee (*Melipona* spp.). These bees are classed with the Honey Bees because they collect very small quantities of honey which is supposed to have

medicinal properties. But they do not secrete any wax to build their combs which are constructed with gums and resinous substances collected from plants and allied to propolis of the true Honey Bees. The combs are built in hollow walls or tree trunks and usually are extended beyond the opening of the hollow in the form of a funnel. The combs yield what is known as "Bees Dammar" or "Pwe-nyet" in Burma, which country has a small inland trade in this substance. The Bees Dammar may be used in varnish and is used in Burma for caulking boats to make them water-proof. The right to collect the combs is leased out by the Forest Department every year and yields an annual revenue of about Rs. 5,000.

The European Hive Bee.

The Honey Bee of Europe is known to Science as *Apis mellifica* (meaning honey-maker) or otherwise as *Apis mellifera* (meaning honey-bearer). It occurs also in Western Asia and Africa. Like the Indian Bee (*Apis indica*) it is found to vary a little in colour, some being darker than others, and also in size and temperament according to localities. In nature the colonies of this bee again like its Indian congener build several parallel combs side by side and in sheltered closed situations, *i.e.*, cavities in tree-trunks and rocks or underground. It is however a very much better honey-gatherer and much less prone to swarming. Figures 1, 2 and 3 in Plate 1, show respectively the queen, the worker and the drone of the Italian variety of the European Bee. The Italian Bees, as they are commonly called, have been found by long experience to be more industrious, more peaceful, therefore less prone to stinging, and more able to guard their colonies against natural enemies, than any of the other varieties. They successfully protect their combs against the Wax Moth. Their queen too is more prolific and therefore the population in their colony is always strong and regains strength quickly even when weakened. On account of these qualities the Italian Bee is rapidly gaining ground everywhere and replacing other bees wherever introduced, not only in Europe but also in America, Africa, Australia and New Zealand, *i.e.*, in countries where bee-keeping is carried on on modern lines.

Which Bee is capable of being kept in Artificial Hives.

Artificial hives are nothing but wooden boxes so designed and made as to afford bees protection against sun, rain, cold and enemies, at the same time allowing them facilities to build combs inside and to go out to collect and bring in the necessaries of their life, *viz.*, honey, pollen and water. Artificial hives are shelters for the bee colonies and are really imitations of their

PLATE V.

Fig. 21.— A colony of the Little Bee in a bush.

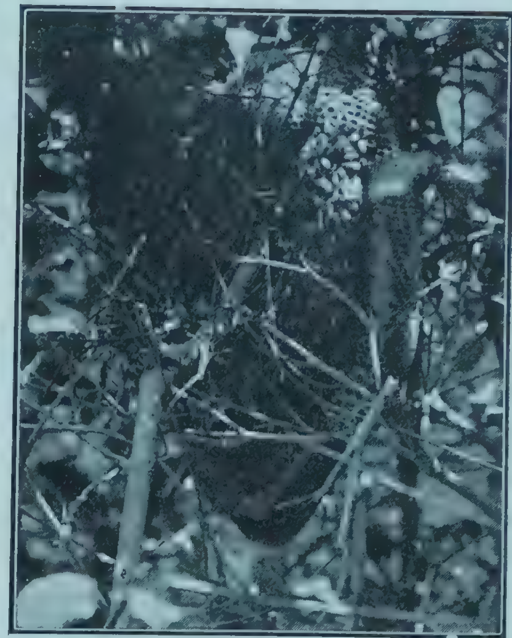

Fig. 22.—The same as Fig. 21, the bees being made to recede to expose the comb.

23.—A colony of the Little Bee at the end of a log of wood.

Fig. 24.—The comb of the colony shown in figure 23.

The flat capping of worker brood and convex capping of drone brood (at the lower part) are quite clear.

natural abodes, *viz.*, cavities of rocks and tree-trunks. Therefore, of the bees we have mentioned, only those which live in such shelters in nature are capable of being kept in artificial hives, *viz.*, the European Hive Bee (*Apis mellifica*) and the Indian Bee (*Apis indica*). Hence they are designated as "Hive Bees." The Indian Rock Bee (*Apis dorsata*) and the Little Bee (*Apis florea*) are lovers of open air and cannot be kept in enclosed boxes; also they build only single combs and are therefore not adapted for hives. Bee-keeping may be described as inducing hive bees to live in artificial shelters or hives under control. In advanced countries there have been various improvements in bee-keeping, all directed towards enabling the bees to gather more and more honey. Of the honey gathered, the bee-keeper takes the surplus over the requirements of the bees themselves. Therefore the more the honey gathered by the bees the greater the profit of the bee-keeper.

Which bee to keep.

As pointed out, of the three indigenous bees of India, only the Indian Bee is capable of being kept in artificial hives. The pictures given will enable it to be distinguished easily. Besides if it is remembered that this bee builds several parallel combs at the same place, no mistake can be made. The Rock Bee and the Little Bee build only one single comb. The qualities which make hive bees desirable are the following :—

1. They should be peaceful in temperament and not prone to stinging, and so easy to handle.

2. Their queen should be very prolific so that the population of the colony may be kept up to a good strength and in the season of honey-flow there should be a very large body of workers able to gather large quantities of honey.

3. They should be good honey-gatherers.

4. They should be able to guard the colony, specially against the Wax Moth, of all the enemies. The bee-keeper can help them against the other enemies but it is hardly possible for him to prevent the Wax Moth from creeping into the hive and infecting the combs at night.

5. Above all, they should not be prone to swarming. If they are prone to swarming, they will never yield a large quantity of surplus honey even if they possess in a high degree all the other qualities. As has already been explained the greater the number of workers in a colony, the more the honey gathered and stored. Swarming divides and therefore weakens the colony and this takes place in the season of the honey-flow, that is, just at the time when plants secrete nectar in sufficiently large quantities. Bees prone to

swarming will swarm just when their number has increased and they are in a condition to gather this nectar.

In all these qualities the Italian Bee excels.

The Comb.

As already explained, the cells of the comb are used as cradles for the earlier stages of the bees and as store-houses for honey and pollen. In nature the honey is usually stored in the cells at the upper part of the comb, about the upper third, brood-rearing being done in the lower portion. The store cells are the same in size as the worker cells and as the brood necessary to be reared is mostly worker brood, the major portion of the comb consists of worker-cells. Drone cells are built towards the bottom while queen-cells, when necessary, are built on the margin. (See Figure 25). Both drone and worker cells may be utilized as store-cells. Pollen is stored here and there in certain cells among the brood. The stored pollen looks like a yellow paste and can be easily distinguished. The comb is built with wax secreted by the worker bees. For secreting wax the bees gorge themselves with honey and sit quietly in a cluster thus keeping themselves warm. Wax oozes through the wax-plates (Figure 11) and collects on them in the form of white scales which are scraped off and moulded and worked into combs with the help of the jaws. It has been calculated that according to season, bees eat from 7 to 15 lbs. of honey to secrete one pound of wax. Therefore comb-building is usually done when enough honey is available.

As the different varieties of bees vary in size, the sizes of the cells of their combs also vary. The comparative sizes of the cells of the combs of the Italian, Indian and Little Bees are illustrated in Figure 25.

In the linear inch are included about $4\frac{3}{4}$ worker-cells of the Italian Bee, 6 worker-cells of the Indian Bee and 9 worker-cells of the Little Bee. The worker-cells of the Italian Bee are about equal in size to the drone cells of the Indian Bee and the worker-cells of the latter are about equal to the drone cells of the Little Bee. The worker-cells of the Rock Bee are about equal to the drone cells of the Italian Bee, 4 or $3\frac{3}{4}$ of which come in a linear inch. Similarly the thickness of the comb is different in the different varieties. It is therefore clear that combs of one variety of bees cannot be used by another variety.

The prevalent condition of bee-keeping in India.

As already explained the Rock Bee and the Little Bee are not capable of being kept in hives. They live in a wild state and the honey and wax from

EXPLANATION OF PLATE VI.

Fig. 25.—A. Comb of the Italian Bee; a few drone cells are seen near the lower margin; an old open queen-cell is shown separately on the left.

B. Comb of the Indian Bee; many drone cells are seen in the lower portion on the right hand side; an open queen-cell is shown separately on the left side.

C. Comb of the Little Bee; drone cells are seen at the lower part; three open and somewhat mutilated queen-cells are seen in the natural position.

D. Workers of the Italian Bee, the Indian Bee and the Little Bee (left to right) to show their comparative size.

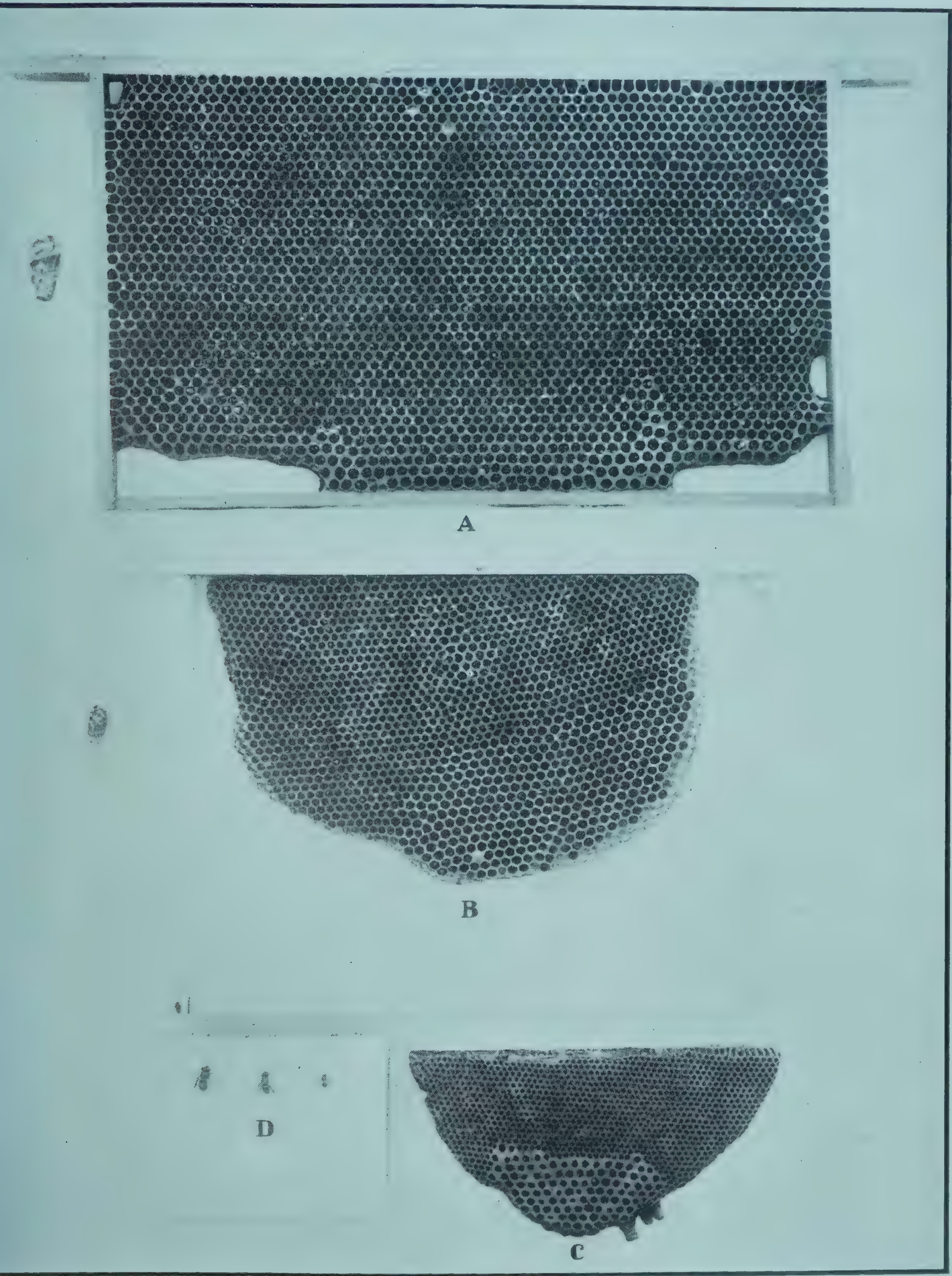

Fig. 25.—Combs of various bees.

their combs are collected in the proper season. They will most probably remain as they are and unaffected by any improvement and progress of bee-keeping in India. The Hill varieties of the Indian Bee being more amenable to control and less prone to swarming and migrating than the Plains varieties, from time immemorial they have been kept by the inhabitants of the Hills. The hive used is not however much of an improvement upon their natural abodes, *viz.*, cavities in tree-trunks and rocks. In the Khasi Hills and in some parts of the Eastern Himalayas the hive used is a thick log of wood, measuring about a yard in length and about 1⅓ ft. in thickness, which is hollowed out and the ends closed with planks leaving a small opening at one end for the bees. These " log hives " are placed horizontally either on the ground or hung on to the eaves of huts. Practically all over the Himalayas up to an elevation of about 7,000 feet the hive used is an oblong niche or recess in the wall inside the house having a small opening on the outside forming the entrance hole for bees, the recess itself being closed with a hinged plank which can be opened or shut when necessary. Thus there is a closed chamber and the bees build combs from its ceiling. The third type of hive used is either an ordinary earthen pitcher turned upside down, for instance, in Coorg and Mahableshwar or other forms of earthen vessels, hemispherical or cylindrical, as in some parts of Baluchistan. These earthen or pottery hives are either placed on the ground or on branches of trees. Sometimes old packing cases or tea-packing chests are taken possession of by the bees which are then allowed to live in them.

The methods too of keeping the bees are primitive. The bees build combs fixing them permanently on the ceiling of the hive chamber. When they store honey they are usually smoked out or sometimes burnt and the combs containing honey are cut out, the honey being afterwards squeezed out and the squeezed combs melted into wax.

Bee-keeping is practised nowhere in the Plains although bees occur plentifully in some places, building combs in cavities in trees and walls and in unused boxes. In many places, for instance, in the neighbourhood of Pusa, there are professional bee-men known as *Koeris* who, in the months of April and May, go about extracting honey from these wild combs. The owners of the boxes, houses and trees get half the quantity of the honey extracted. All the combs are cut out, the portions containing the brood are rejected and those containing the honey are squeezed. This honey the *Koeris* hawk about, selling it at 5 to 8 lbs. per rupee. The honey contains many impurities in the shape of wax, pollen and certainly also the juice of some eggs, grubs and pupæ. Therefore it does not keep and ferments quickly and is ultimately reduced to the condition of a thin and not infrequently sour syrup.

Large quantities of honey are similarly obtained from the combs of the Rock Bee.

Besides the professional hawkers there are dealers in Calcutta alone who sell about 60,000 to 70,000 lbs. of this thin fermented honey at about the same rate as mentioned above. There is no export trade, the whole of this quantity finding its way into villages where it is stocked and sold by grocers. The honey produced in the Hills is of a better quality and is obtained in a thick granulated condition. It is sold at 8 annas to 10 annas per pound. That produced in the Darjiling Jail is sold at the very high rate of a rupee a pound.

There have been several attempts by private gentlemen and missionaries at keeping the Indian Bee in the modern European methods. But they have either not been successful or have not given better results than the prevalent indigenous methods principally, it appears, for want of proper appliances. Without these appliances bees cannot be properly controlled.

Modern bee-keeping.

In the following pages the modern advanced methods of bee-keeping are described with detailed instructions about making the hives and appliances necessary and about the proper management of both the Indian and the Italian Bees. The improved methods are directed towards bringing the bees as much under control as possible, giving them facilities for gathering and storing larger quantities of honey so that larger surpluses may be obtained and securing the surplus in as pure a condition as possible. The principal improvements in appliances may be briefly enumerated as follows :—

(1) *The movable bar-frame hive.*—The bees are made to build combs separately in wooden frames and all the combs in a hive are capable of being taken out, examined and reinserted whenever necessary.

(2) *The honey-extracting machine.*—The combs built by the bees are not broken or destroyed. The honey stored in them is taken out or as it is called "extracted," in a machine and the combs given back to the bees to be used by them again. Therefore the bees are not required to build fresh combs every time and are thus saved from secreting wax which involves time which can be otherwise usefully devoted in gathering honey and also involves consumption of large quantities of honey. Therefore by preserving combs the bee-keeper increases the surplus.

PLATE VII.

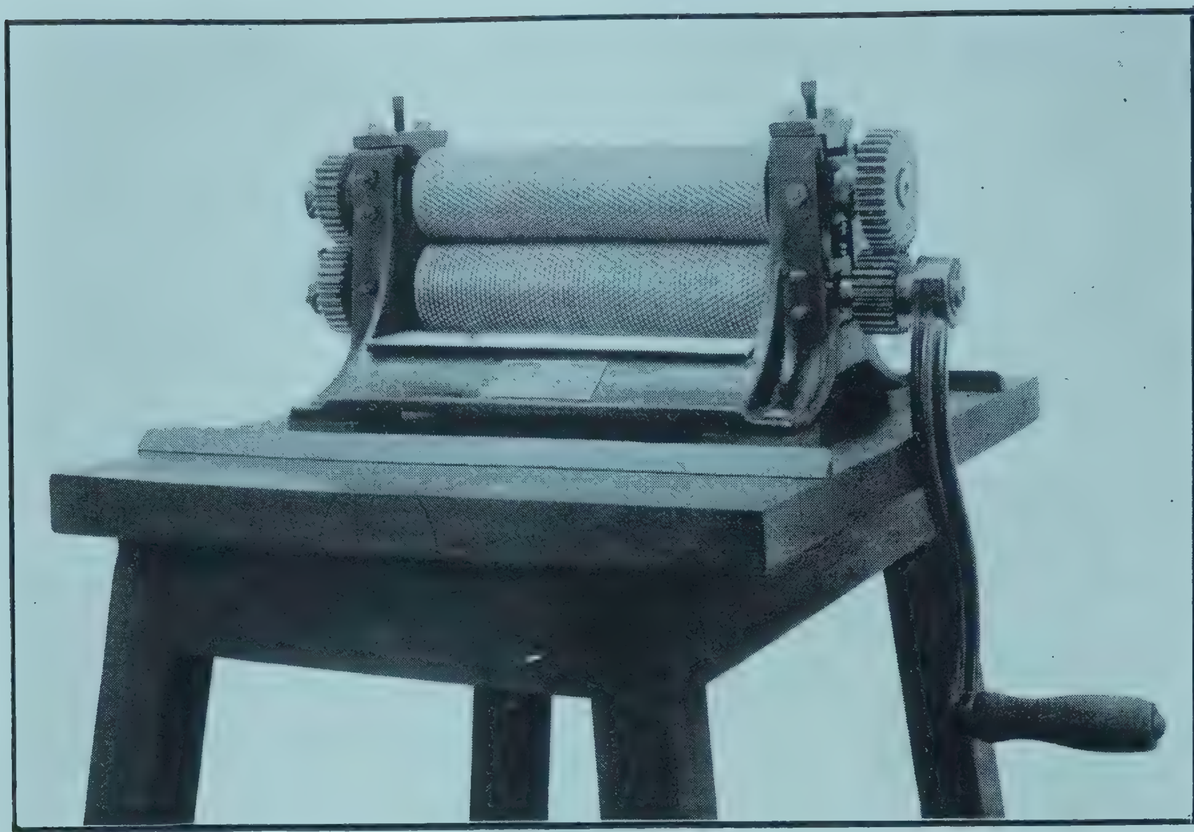

Fig. 27.—Comb foundation mill.

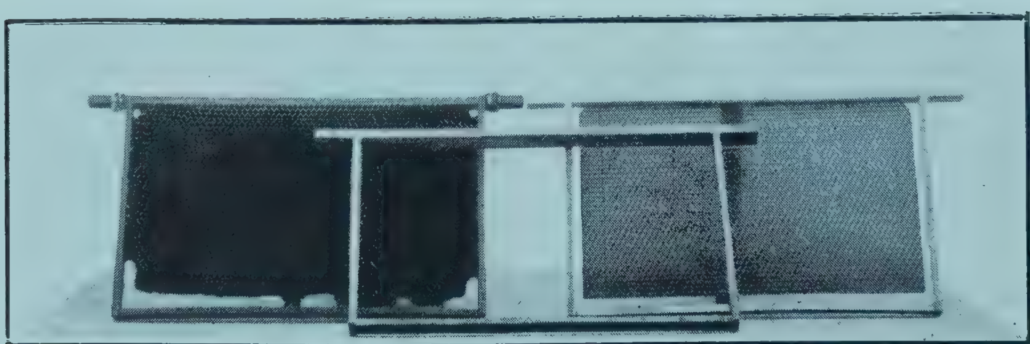

Fig. 28.—An empty frame in the middle. The frame on the right is fitted with a sheet of artificial comb-foundation. On the left a comb built on such a foundation in a frame.

(3) *Artificial comb-foundation.* (Figure 26).—In order further to save the bees from secreting wax, a thin sheet of wax is provided on which the bees build the comb. The bases of the cells of the future comb are artificially imprinted on this sheet by passing it through a special roller machine (Figure 27). In order to build the comb the bees have only to add the walls of the cells. They have to secrete a certain amount of wax no doubt but they use much of the wax provided in the comb-foundation. As the cells of the combs of the Italian and Indian Bees are different in size the foundation ought to have the cell-bases of the proper size imprinted on it to suit either. Figure 28 shows an empty wooden frame, a frame fitted with artificial foundation and a comb built on such a foundation in a frame.

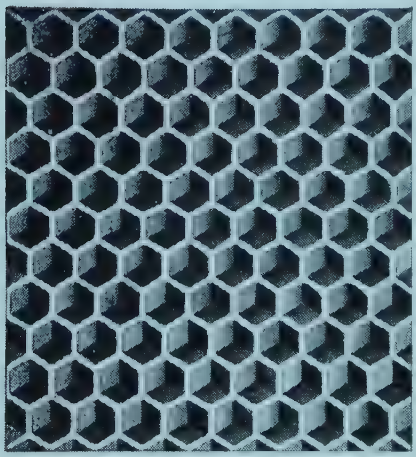

Fig. 26.—Artificial comb foundation.

(4) *The queen-excluder.*—In order to secure honey free from brood and pollen, the queen is prevented from having access to some combs in the hive by means of a perforated zinc sheet. Workers can easily pass through the perforations and store honey in these combs but the queen being larger in size cannot pass through them. This is known as the "queen excluder" zinc sheet. By using the queen-excluder the bees can be made to store only honey in some combs, no eggs being laid in them as they are out of reach of the queen. As pollen is stored in combs in which brood is being reared, these combs being free of brood, remain free of pollen as well. The honey is thus obtained in a pure state, free from pollen and juice of crushed brood which is sure to be injured in the process of extracting honey if present in the comb. As the workers of the Indian Bee and the European Bee are different in size, different sizes of perforations are necessary to adapt the queen-excluder to either. For the European Bee the perforations measure $\frac{3}{4}$ inch $\times \frac{1}{6}$ inch. For the Indian Bee they measure $\frac{5}{32}$ inch $\times \frac{5}{8}$ inch.

The Hive.

The log and pottery hives at present used in different localities should be replaced by movable bar-frame hives.

The Kerosene-box Hive.—A cheap hive can be made from ordinary kerosene packing cases. Such a hive is illustrated in Figure 29. A wall is

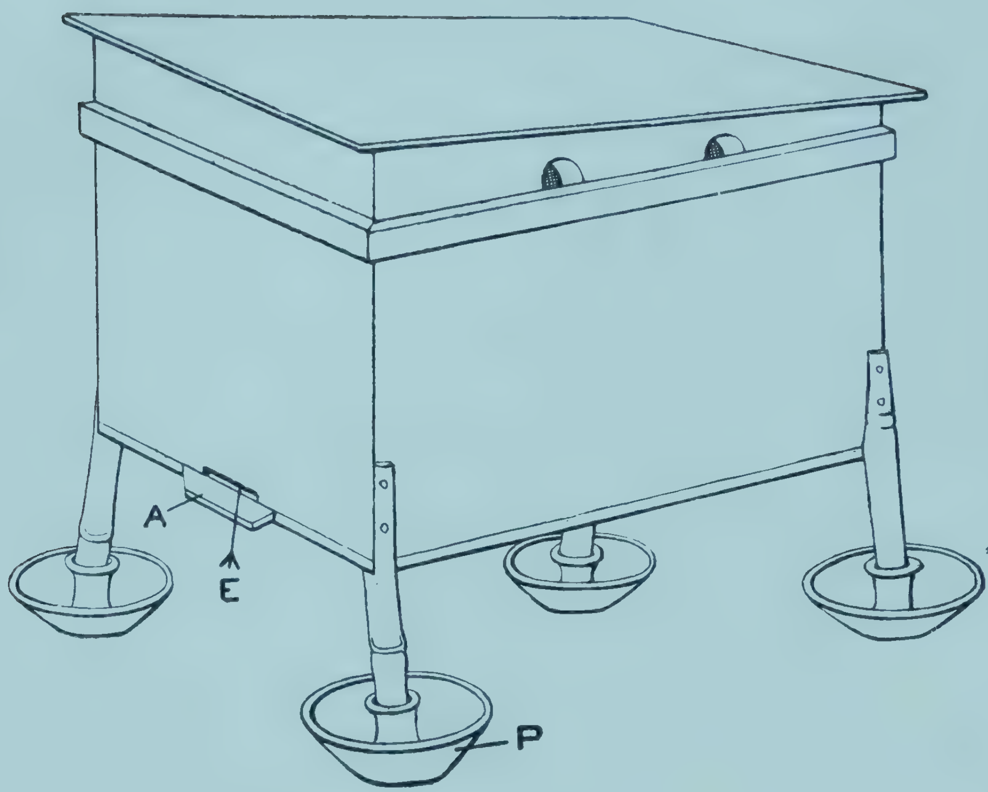

Fig. 29.—Kerosene-box hive.
E. Entrance. A. Alighting board for bees.
P. Ant-preventer (it is kept filled with water).

added inside along each of the longer sides as shown in Figure 30. The frames of combs are supported on the top of these inside walls as shown in this figure. A hole is made at the bottom at one end and a small piece of

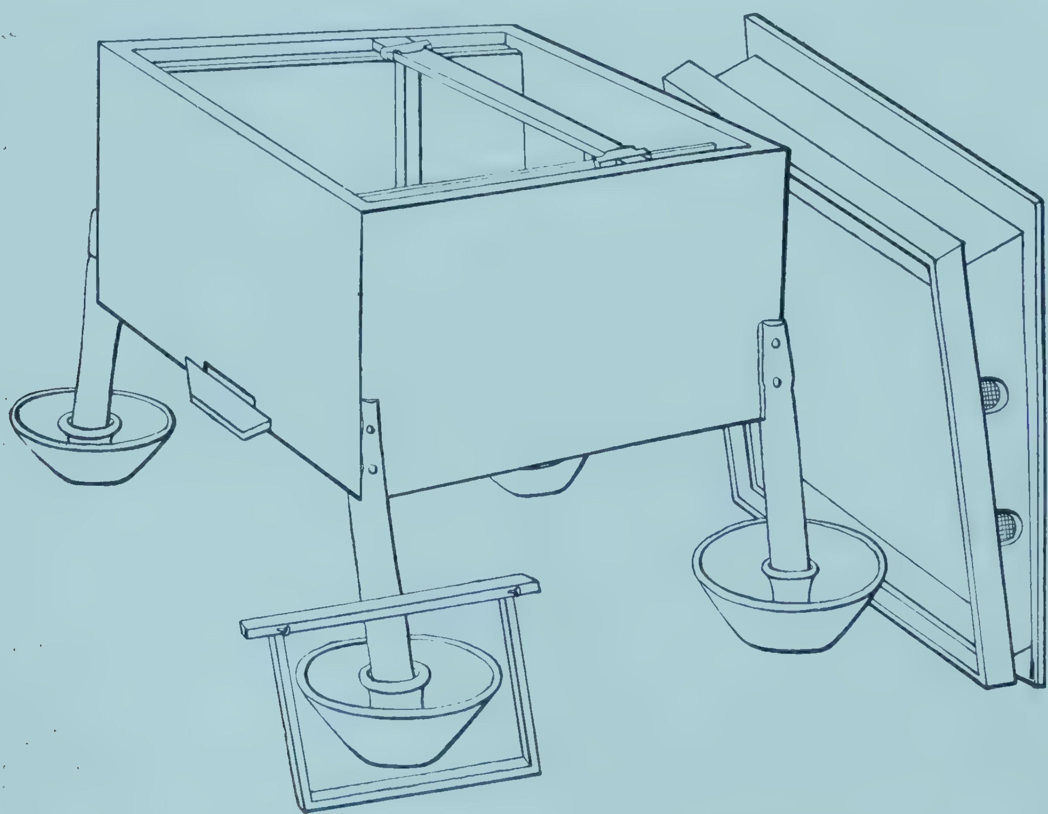

Fig. 30.—Kerosene-box hive opened; with one frame in position and another outside.

wood nailed below; it forms the alighting board for the bees. Four pieces of bamboo are nailed on to the box and form legs. The cover, or roof, is made sloping and is covered by a piece of tin cut from an ordinary kerosene tin. This prevents rain from getting in. Such a kerosene-box hive may do well in the Plains. But in the Hills where there is too much rainfall and also severe cold, it does not afford sufficient protection to the bees. The measurements of the frames used for this hive are given in Figure 39. This frame should be adhered to in every case. The inside measurements of this hive are given in Figure 31. The kerosene boxes vary

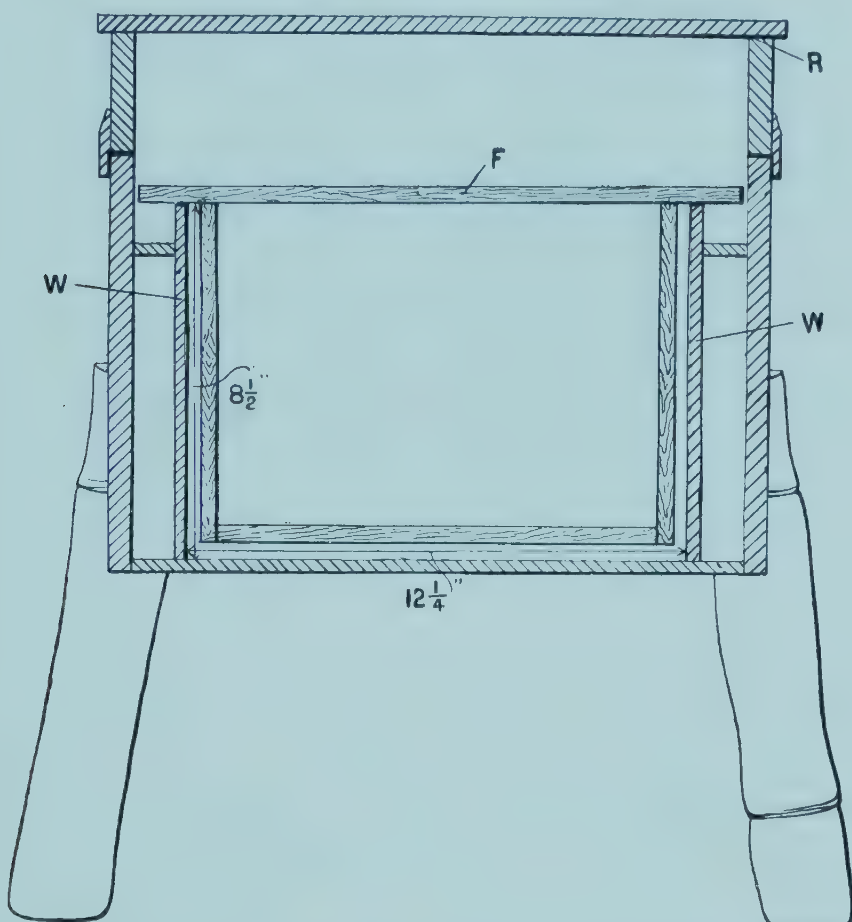

Fig. 31.—Section through the Kerosene-box hive to show measurements.
R. Roof. F. Frame for comb. W. Walls which are added inside.

a little in size, but by varying the position and height of the newly added inside walls, these measurements can be obtained. The longer standard frames (Figure 40) cannot be used in the kerosene box-hive, but they can be accommodated lengthwise by adding two more walls along the shorter sides of the box, so as to make a chamber 14½ to 15 inches in length.

The Standard Hive.—Bee-keepers will find by experience that it will give more satisfaction and pay in the end to make a hive with well-seasoned *deodar* wood or any other wood which will not warp or in other ways be affected by changes of seasons. When making a hive with such wood it is always advisable to make it of the standard pattern shown in Figures 32—35 The standard hive is so made that its parts can be separated a shown in Figure 33. The bottom, or as it is called "floor board," has four legs

Fig. 32.—The Standard hive with a comb shown outside.

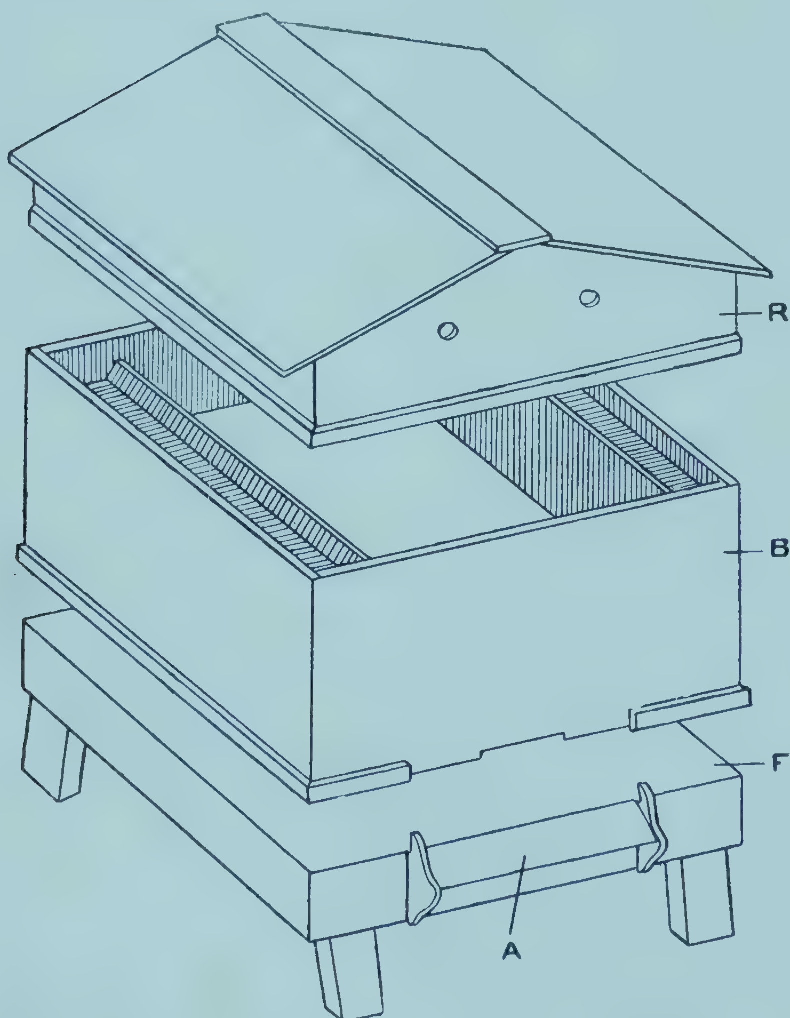

Fig. 33.—Parts of the standard hive shown separately.

R—Roof. B—Body box or hive chamber.

F—Floor board or bottom of the hive. A—Alighting board for bees.

fixed to it and a piece of sloping board in front of the entrance to serve as an alighting board for the bees. The combs are contained in the hive chamber or "body box" as it is called, and are supported on the top of the two inner walls. The roof rests on the body box. The measurements of the standard hive are given in Figures 34 and 35 and those of the standard

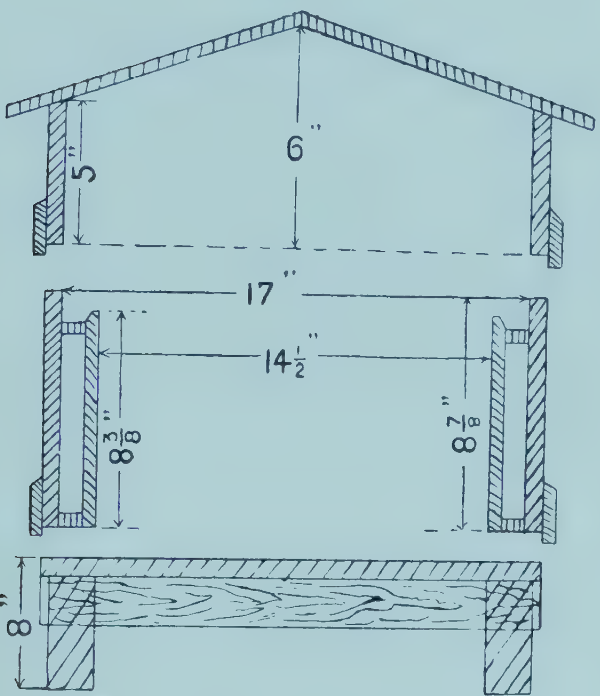

Fig. 34.—The standard hive, section from side to side.

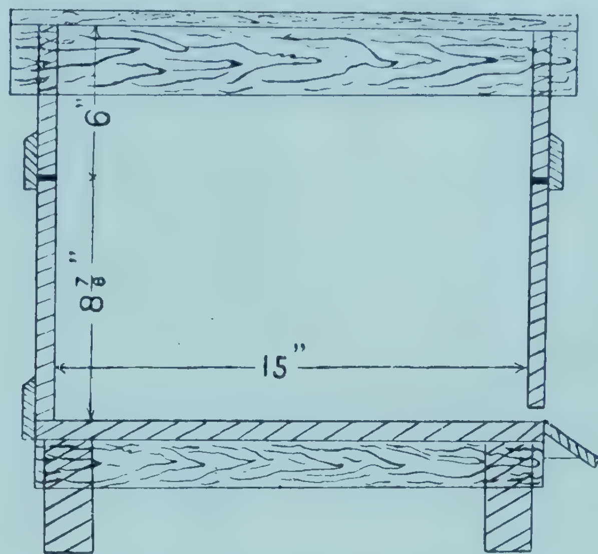

Fig. 35.—The standard hive, section from back to front.

frames for use in this hive are given in Figure 40. When the hive is placed in the open air a porch or portico above the entrance may be added as seen in Figure 32.

The Wall Hive.—The wall hives with a little modification can easily be adapted to the use of moveable bar frames and then they will be superior to any wooden hive, considering the severe winter prevalent in the places where wall hives are used. In Western Countries there is great difficulty in keeping bees warm in winter. When the hives are left outside they have to be wrapped in warm materials. In order to minimize the difficulties in thus attending to every hive, special cellars are in many cases prepared into which the hives are carried and stacked. In the case of the wall hives there is no difficulty in this respect. In places with severe cold, wall-hives will serve the purpose well and will be found equally efficacious in the Plains. In order to be able to use movable bar frames in a wall hive, it should be made correctly according to measurements which are given in

Figure 36. It should be made as it is now done but with the modifications according to the measurements given. There should be grooves at correct heights and into these grooves a movable frame carrying combs will be put

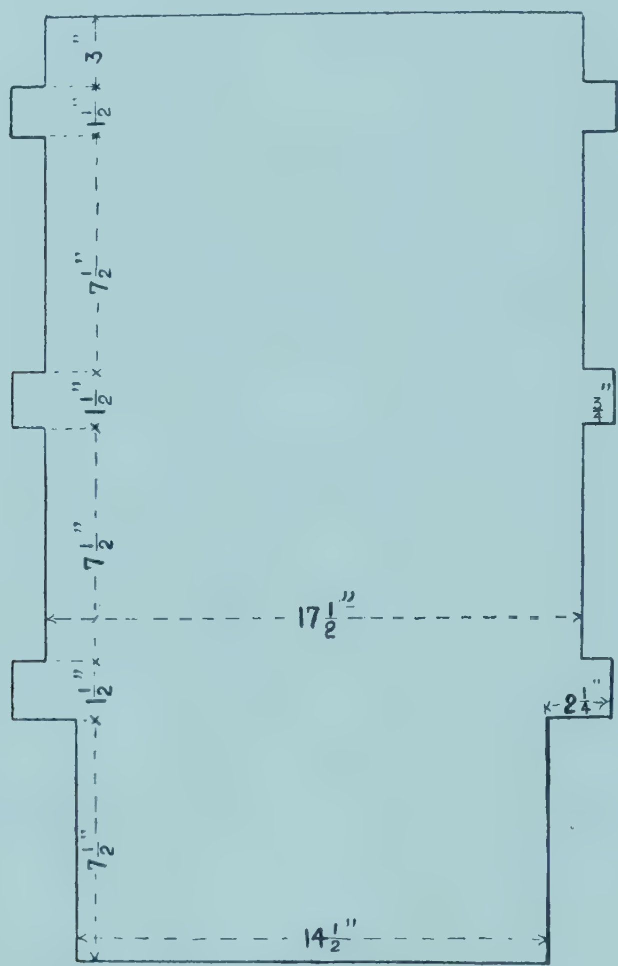

Fig. 36.—Measurements of the wall hive.

in. The frame of combs can be inserted or drawn out as shown in Figure 37. Every 9 inches will accommodate one layer of standard frames. Therefore in the hive recommended three layers of combs can be put in when necessary. The lowest chamber will ordinarily be used for the Indian Bee. The Upper chambers will be required for use when Italian Bees are introduced. All the standard appliances of the British Bee-keepers' Association can be used without any modification.

The hive can be made 30 inches high. For 7½ inches from the bottom the breadth will be 14½ inches. Then there are two grooves to receive a comb-carrier frame. Above this the breadth will be 17½ inches. In order

to accommodate 10 combs for Italian Bees in each chamber the depth

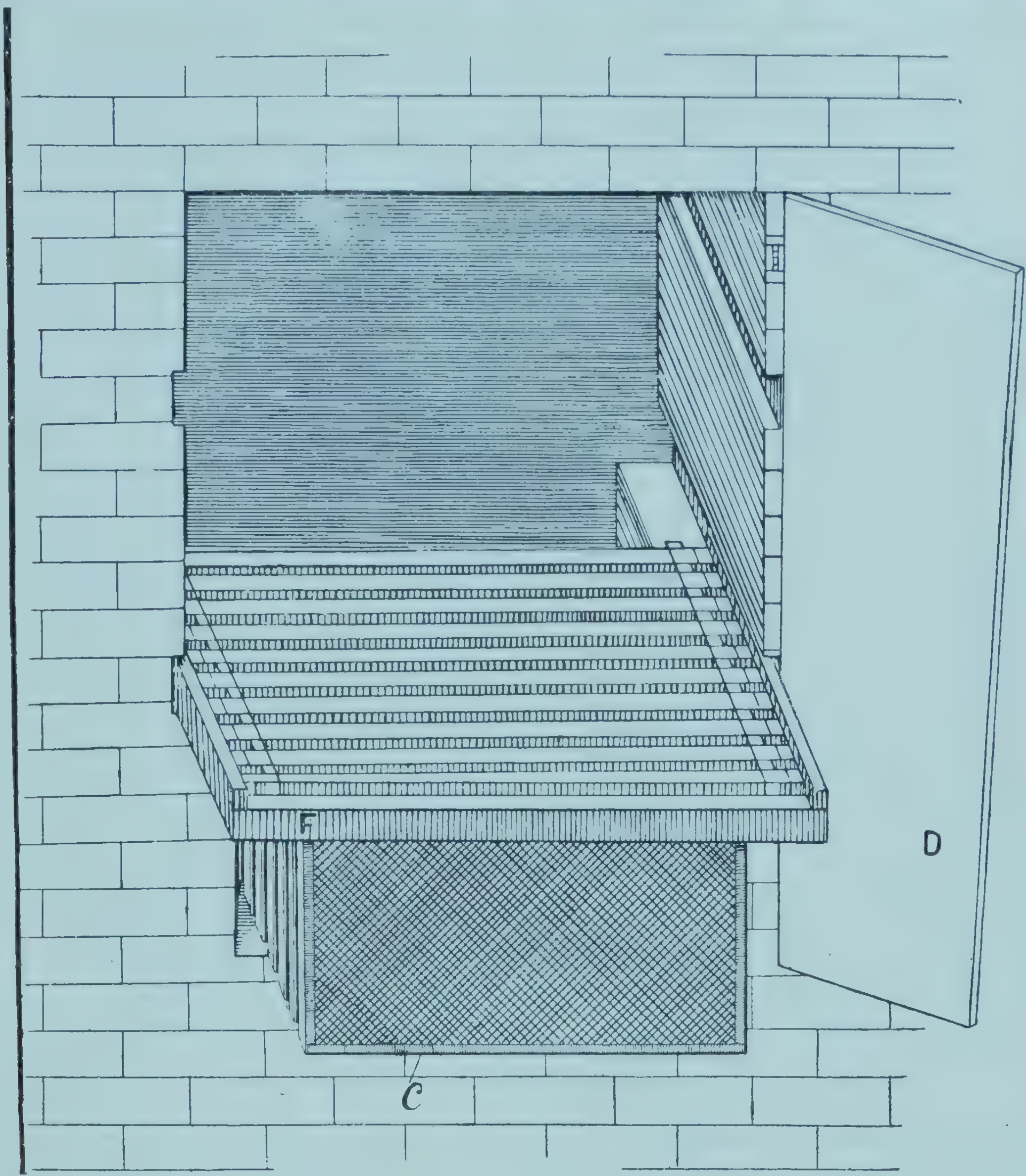

Fig. 37.—Movable bar-frame wall hive. The door (D) has been opened and the comb-carrier frame (F) with the combs (*c*) in position has been half drawn out.

of the hive should be 15½ inches. Every 1½ inches accommodates one comb and the depth can be decreased accordingly if the thickness of the wall does not allow of full 15½-inches. The walls and floor should be made smooth and level and all the corners well made. A correct make is essentially necessary for smooth working.

When it is necessary to examine the hive the hinged door is opened and the comb-carrier frame drawn out (Fig. 37) and any comb taken out and examined. It is not necessary to draw off the carrier frame entirely from the grooves. It is held in position even when more than three-fourths pulled out and both the hands of the operator are free to examine combs.

The comb-carrier frame for the wall hive is illustrated and its measurements given in Figure 38. A A are two pieces of wood 15″ × 2″ × 1″. Over

them are placed two pieces of wood B B measuring $15'' \times 1'' \times \frac{1}{2}''$. C C are two pieces measuring $19'' \times 1\frac{1}{4}'' \times \frac{1}{4}''$ nailed on to A A in the manner shown.

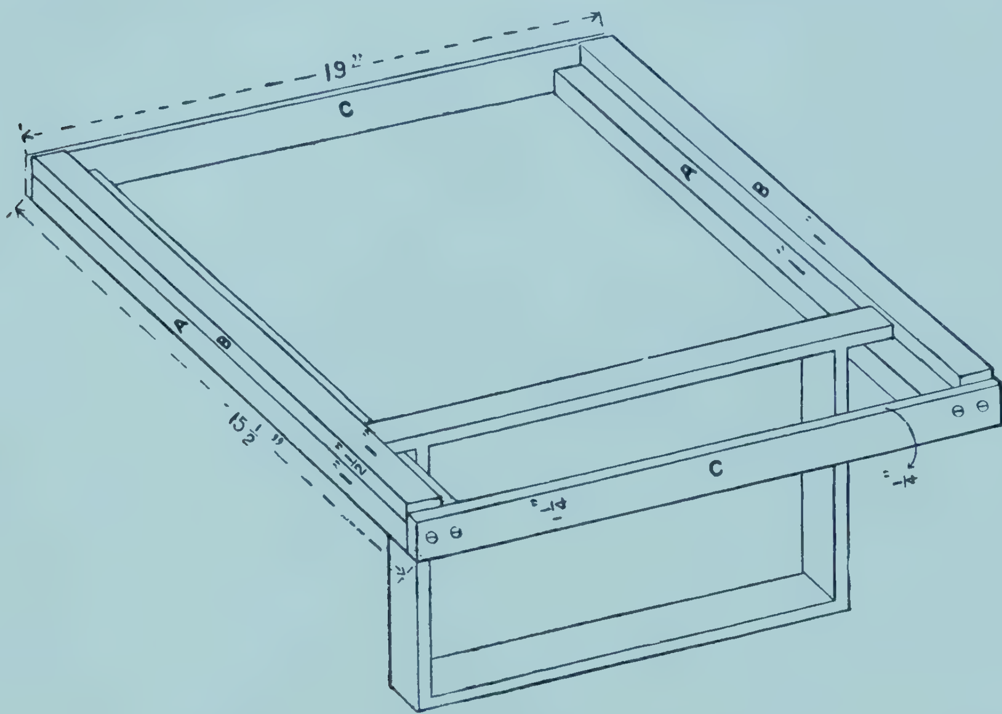

Fig. 38.—Comb-carrier frame for wall hive.

This frame will accommodate 10 combs of Italian Bees and 12 combs of the Indian Bee. The frame carrying combs runs into grooves as shown in Figure 37. If the depth of the hive cannot be full $15\frac{1}{2}$ inches, the comb-carrier frame should be shortened by $1\frac{1}{2}$ inches for every comb.

The Frames for Combs.

The measurements of the frame for kerosene box hive are given in Figure 39 and those of the standard frame in Figure 40. The frames are made

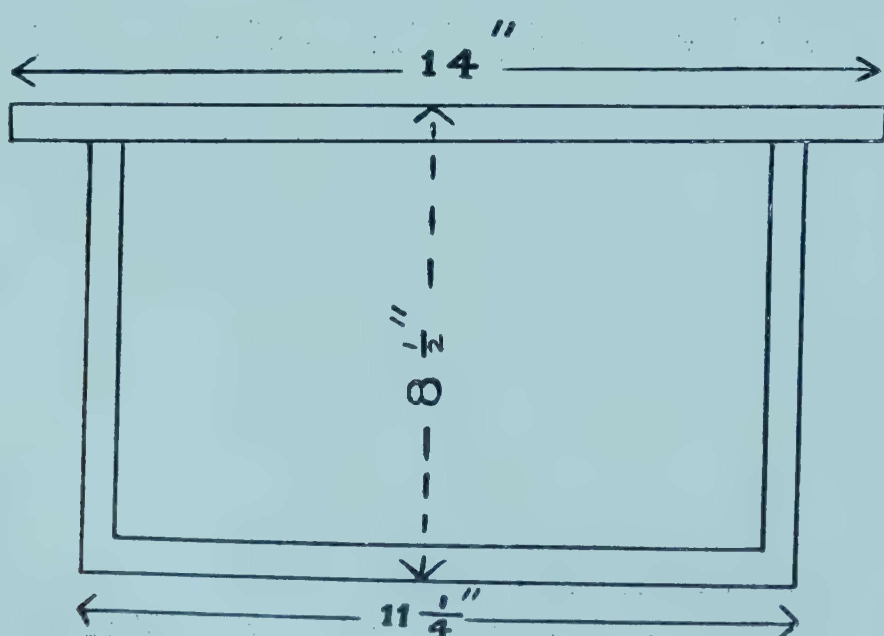

Fig. 39.—Measurement of frame for Kerosene-box hive.

with strips of any well-seasoned wood which will not warp, well-seasoned deal-wood being the best. The strips are made $\frac{7}{8}$ inch wide and $\frac{3}{8}$ inch

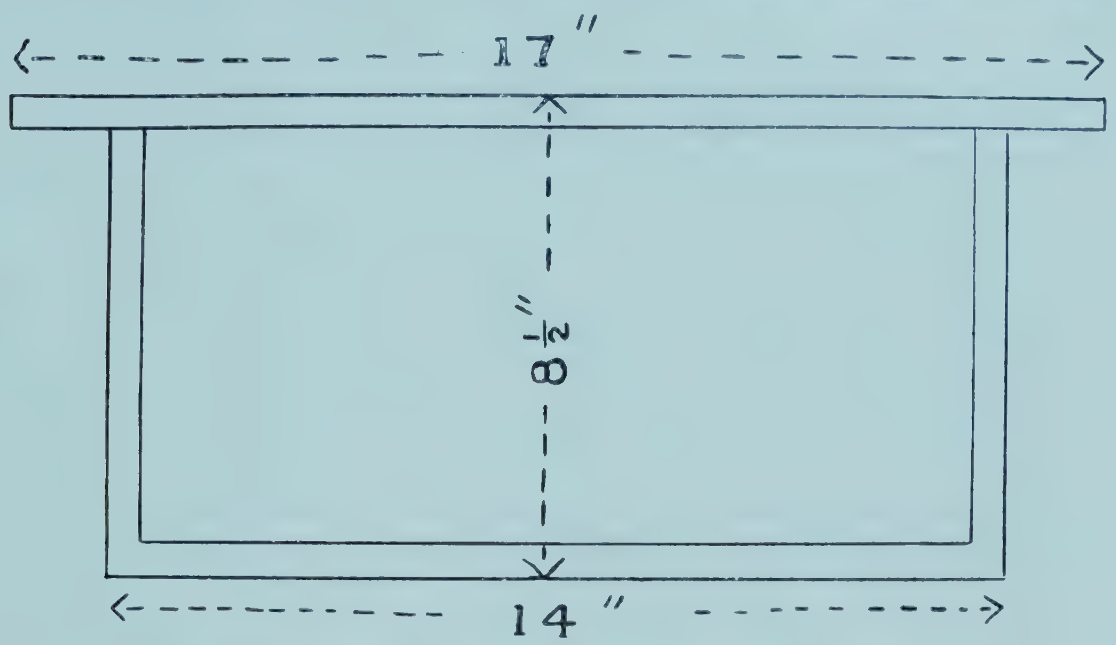

FIG. 40.--Measurement of standard frame for use in standard and wall hives.

thick and are cut and fitted up to make a frame according to the measurements given. The side and bottom bars may be made $\frac{1}{4}$ inch thick. The projecting portions of the top bar rest on the inner walls of the hive. In the standard frames manufactured and sold, there is an open slit along the middle of the top bar to receive the sheet of comb-foundation. It is not advisable to have this slit as it affords a very convenient hiding place for the Wax Moth caterpillars. A small groove about $\frac{1}{16}$ inch deep along the middle of the under surface of the top bar (Fig. 41), serves the purpose very well for adjusting the foundation sheet.

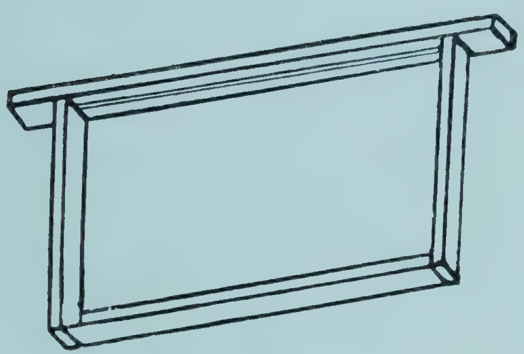

Fig. 41.—Frame with groove along the middle of the under surface of the top bar.

How Bees can be made to build Combs in Artificial Frames.

In nature the parallel combs are built at a regular distance leaving enough space between them for the bees to walk over the contiguous combs. In the case of the Italian Bee the distance between the centres of the contiguous combs is about $1\frac{3}{8}$ inches while in the case of the Indian Bee it is about $1\frac{1}{8}$ inches. When artificial frames are used they are to be kept at the necessary distance from one another and this distancing or spacing

is secured by tin frames called " metal ends " fitted to the projecting ends of top bars as illustrated in Figure 42. It can also be done by putting a nail at each end of the top bar of the frame. But the metal ends are very convenient and cheap. For correct spacing of the frames of combs in the case of the Italian Bee, every frame is provided with these metal ends (Fig. 43). For the Indian Bee the same metal ends will give the correct spacing when used in every other frame as shown in Figure 42. If the frames are correctly spaced in the hive and if the lower surfaces of the top bar are smeared with a little wax, the bees will build a straight comb in the frame. Smearing is done by melting the wax over fire and applying it with a brush or stick. The comb, in the middle in Figure 25, is such a one built by the Indian Bee. Proper distancing should be observed even when the frames are provided with sheets of comb-foundation. When comb foundation is supplied, the top bars of the frames need not be smeared with wax.

Fig. 42.—Spacing of frames for the Indian Bee. M—Metal end.

Fig 43.—Spacing of frames for the European Bees.

Use of Comb-Foundation.

The purpose of using the comb-foundation has already been explained (page 31). Either full sheets of foundation may be used as shown in Figure 28 or only a small strip as shown in Figure 44 to form the guide or starter for the comb which the bees are intended to build. The use of a full sheet of foundation has one advantage. The bees at once fill the entire frame with comb and combs with uniform worker-cells or drone-cells are obtained. When only a guide or starter is used the comb is built as in nature and is usually of the form illustrated in the middle in Figure 25 and many drone-cells may be formed in the lower part. The foundation is fitted into the groove on the under surface of the top bar of the frame.

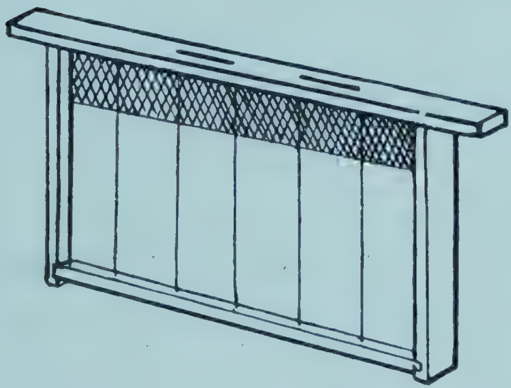

Fig. 44.—Frame with starter foundation.

Wiring Frames.

In order to strengthen the comb in the movable bar frame the frames are wired as shown in Figure 45. A thin copper or tinned wire is used.

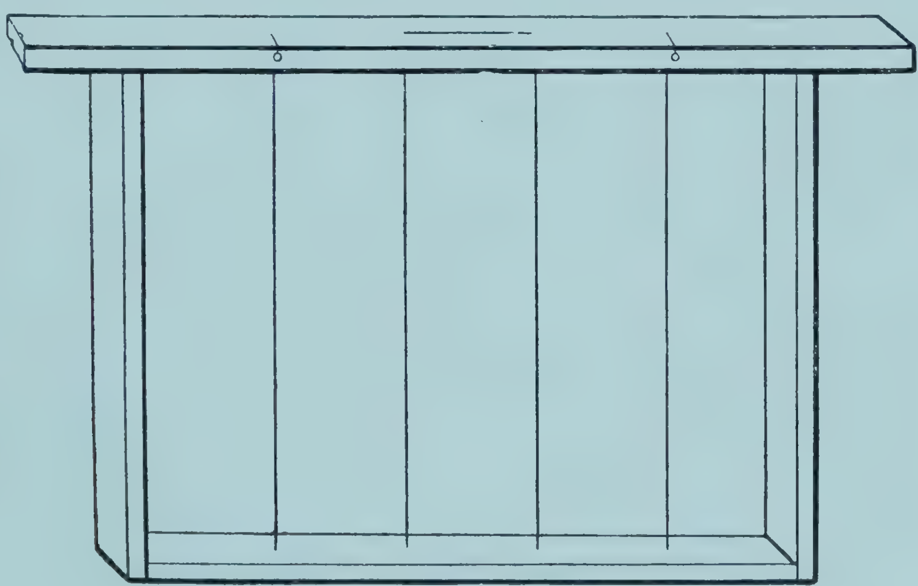

Fig. 45.—Frame wired.

A tinned wire is specially manufactured and sold for this purpose. The wire passes through the middle of the top and bottom bars of the frame, and of the comb when it is built. The comb is therefore held tightly in the frame and there is little risk of its breaking and falling off the

frame in manipulation. After wiring the frame the foundation-sheet is fitted into it and the wire is embedded into the foundation by means of an embedder. Any round metallic disc can be converted into an embedder. A copper coin, a pice (Fig. 46) or half-pice does very well when a groove

Fig. 46.—" Pice " wire-embedder.

is made all round the middle of the edge with a thin file. A hole is then made into the centre and the disc fitted on to a flat iron handle loosely so that it can revolve easily. Wire embedders are sold ready-made. One called the Spur Wire-embedder is illustrated in Fig. 47. There is a groove

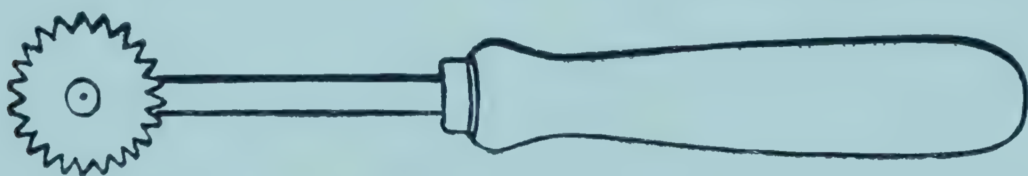

Fig. 47.—Spur wire-embedder.

in the spurs. The embedder is heated over a fire or flame and placed and run on the wire which fits into the groove (Fig. 48). The heat melts the

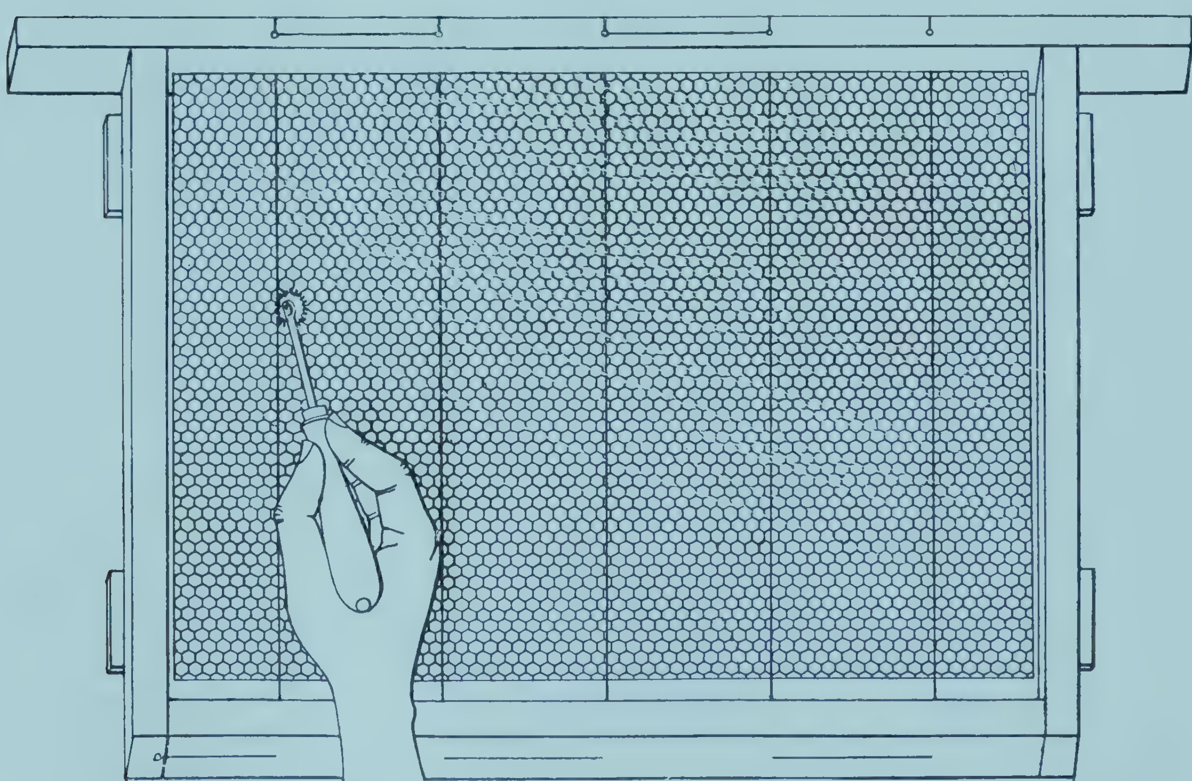

Fig. 48.—Embedding wire into foundation.

wax of the foundation. Therefore the wire gets into the sheet and is held in it when the wax cools down and solidifies.

In order to embed the wire into the foundation, the frame with the foundation is placed on a board (Fig. 49) ½ inch thick and of the size of the inside measurements of the frame.

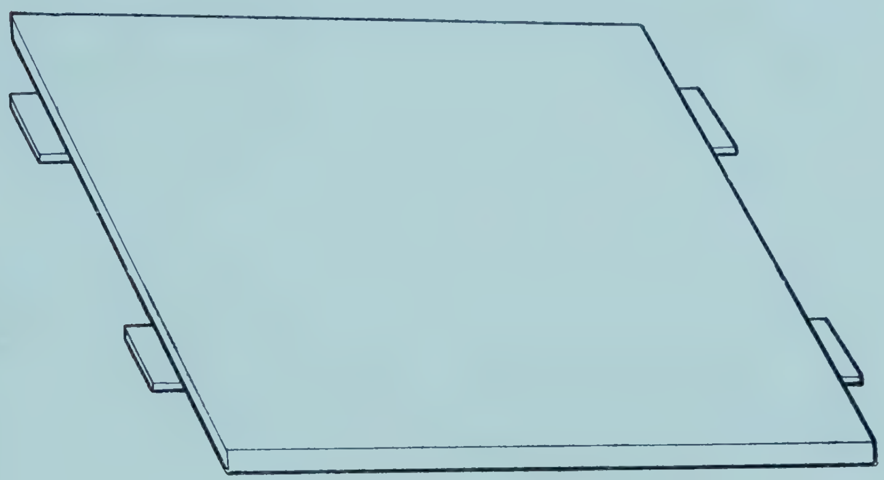

Fig. 49.—Wire-embedding board.

The Honey Knife.

The honey knife is shown in Figure 50. Both the edges as well as the tip are sharpened so that it cuts either way, and also by the tip. The handle is raised from the line of the cutting edge so that the knife can be worked flatly on a surface without the fingers of the holder interfering. Every bee-keeper should have at least two of such knives. They are easily made by local blacksmiths. This knife is useful for all kinds of work in connection with bee-keeping.

Fig. 50.—The honey knife.

Arrangement in the Hive.

The frames of combs are placed in the hive and a piece of thin gunny cloth, blanket or oil cloth (American cloth, the enamelled side downwards) of the size of the inside measurements of the hive, is placed over the frames so as to cover all the frames. This is called a quilt. Several folds of warm quilts may be necessary to keep the bees warm in the cold weather. In the hot weather only one sheet may be sufficient. Only so many combs are kept as can be covered by the bees. If the combs do not fill the entire hive, they are pushed towards the entrance and a wooden partition, called a division board or dummy (Fig. 51) is placed behind them, thus

Fig. 51.—Dummy or division board.

producing a chamber closed all round. The dummy is an ordinary wooden board about ½ inch thick, on the top of which a bar is fixed and the two projecting ends of this bar rest on the inner walls of the hive like the ends of the top bar of a frame.

Location.

In India vegetation is so common and rich that any place will probably be found suitable for keeping bees. The surest test is to find out whether bees occur in a wild state in the place and if they do, the place will surely be suitable. But whether the bees will yield large surpluses has to be found out by actually keeping a few colonies. It is always advisable to find this out before embarking on a large scheme.

As regards actual location of the bees, they should be placed where they will not be exposed to high winds and away from places which are much frequented by men or cattle. Provided there is proper ventilation in the hives and they are not painted black, there need not be any shade against the sun. When placed exposed to rain the roof should be so made or covered with tin that no water may get in. It is an advantage to place the hives so that they may get the morning sun. But in the swarming season it may be necessary to shade them. Hives can be placed under big shady trees and in villages, near the compound walls on the east side facing east. If a workable shed is built over them from the wall this will make a very good place for bees. The bees will get the morning sun, will be protected from the midday sun and rain as well as from high winds. The hives can be placed side by side at a distance of about 6 feet from each other. Wall hives should be on the east and south walls and should be at least about four feet apart. When a large number of hives are kept they can be arranged in rows about eight feet apart and one behind the other. The hives should be so arranged that they stand in between the hives in the succeeding and preceding rows.

Manipulating Bees.

The bee's sting.—It is the sting which deters people from approaching bees. The sting being barbed with backwardly directed teeth, it is held in the place where it is thrust. Not infrequently a portion of the entrails of the bee is also left behind. The bee which is thus deprived of its sting dies afterwards. At the base of the sting there is a minute bag, called poison-bag containing a fluid which causes the irritation and swelling which follow a sting. When a sting is received the part should not be rubbed as is usually done. The sting should be pushed out with the edge of a knife or finger nail by applying the knife or nail at the side. The sting should not be pressed as in that case the poison bag bursts and its contents get into the part stung. If the sting is removed without injuring the

poison-bag, there will not be much irritation or swelling. Several repeated applications of benzene or liquid ammonia will prevent much irritation and swelling. If the swelling is large and painful fomentation with hot water will afford relief. When a person is stung several times he becomes in a way inoculated with the poison and gradually becomes less subject to the evil effects of the sting.

If the bees are handled confidently without fear and very slowly without any sharp quick movements or jarring, they are not at all likely to be irritated and to sting.

Gloves and Veil.—When angry the bees at once fly at the face. Therefore it is always safe to use a veil, as shown in Figures. 57 and 58. It is used over a hat or a big turban so that bees may not be able to reach the skin with their sting even when they sit on the veil. In place of the costly hat or turban, a simple thing can be had made by *doms* (basket-makers) for about half an anna or so. This is shown in Figure 52 and is used in many districts by labourers as a protection of the head against sun. In some places it is known as *matla.* Its use with a veil is shown in Figure 58. The veil is made by sewing a piece of mosquito netting and the portion in front of the eyes should be dyed black for distinct vision. The other parts exposed to the sting are the hands which can be protected by gloves. (Fig. 57.) But it is very awkward to work with gloves on and they can be and are safely discarded after some time when confidence is gained. Provided the body is covered it does not matter what dress is used. (But bees do not like black objects and it is better to wear light-coloured clothes when dealing with bees.—T. B. F.).

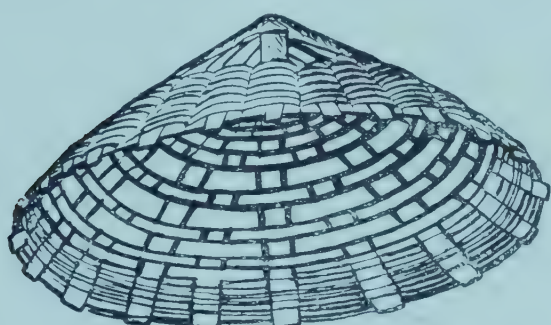

Fig. 52.—" Matla."

Subduing Bees.—Bees have a dislike for, and are rather frightened at, smoke and any strong odour such as that of carbolic acid. Therefore they are subdued when exposed to smoke or carbolic acid fumes, remain quiet and can be handled easily. When the bees are frightened they gorge themselves with honey and when filled with honey they show hardly any inclination to sting.

Smoke of burning rags or wood may be blown on them. Tobacco smoke is rather too strong. For smoking bees, a special and very convenient smoker is manufactured and sold. (Fig. 53.) It has a cylindrical tin fire-box with a detachable nozzle and a pair of bellows fixed

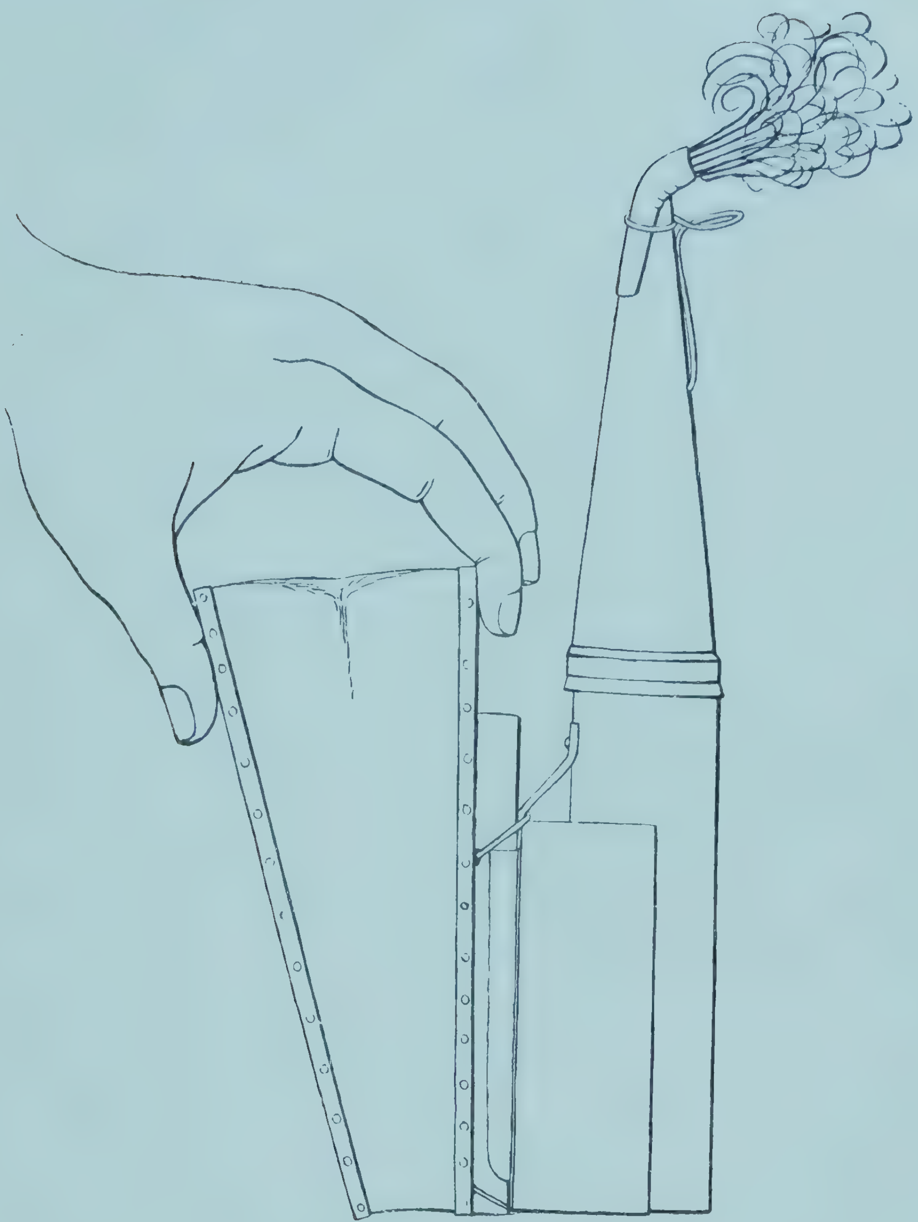

Fig. 53.—The Bingham Smoker.

to it. Rags or pieces of wood are put in the fire-box and lighted and the bellows worked with hand. The smoke comes out through the nozzle and can be directed in any direction.

Carbolic acid is used in solution in water. One part of carbolic acid and two parts of water are mixed and well shaken. A piece of cloth is dipped in this solution and the water wrung out. When this cloth is presented the smell of carbolic acid causes the bees to recede quickly.

Precautions in manipulation.—Open the hive slowly, with slow movements and without producing any jarring. Take out and replace combs similarly. Avoid quick movements of hand, body or appliances used. Avoid crushing a bee. The smell of a crushed bee irritates the others very

much. Similarly the smell of a sting irritates them. If a sting has been received, and stings are frequently received on the gloves in bad manipulation, it is better to walk away slowly to a little distance. Then remove the sting and blow a little smoke on the part stung to hide the smell.

How to procure Bees and make a Start.

Italian bees are not available in India and even when they will be available they will have to be purchased. Colonies of the Indian Bee are easily procurable in the swarming and migrating seasons. The swarming season is in spring in the Plains and in the Hills once in September-October and again in March-April. To places near the Hills bees migrate in late winter and early spring. Similarly they migrate to the Hills in early autumn. They can be secured in three ways :— (1) by using decoy hives, (2) by capturing swarms and hiving them and (3) by hunting out and hiving colonies which have already settled in cavities of tree trunks or walls or in the ground or in unused boxes.

(1) Decoy hives are ordinary hives so arranged and placed that swarms come and occupy them. Six frames fitted up with metal ends and starters of foundation are placed in the hive with a dummy behind, and covered with quilts. The hive thus fitted is placed in a sunny situation, preferably shaded at midday, for instance, under a big tree or by the side of a wall. In the Plains decoy hives should be placed out early in January and in the Hills in September and March. Occasionally the hives should be visited to see if bees have come and occupied them and that the frames have not been displaced. If the frames are not properly distanced combs will be built across them, cementing them together.

(2) If a look-out be kept for bees in the swarming and migrating seasons, stray swarms will be found to settle in bamboos and bushes and sometimes on open places such as a branch or trunk of a tree or a wall. They should be looked for from midday till late in the afternoon. When a swarm has settled in an accessible place it can be captured in the following manner. Take a small wooden box about $8'' \times 8''$ and about $6''$ deep. A smaller box may do if the swarm is small. One side should be open and the wood or at least the inside of the box should be rough and unpolished. Have smoke ready in the smoker. Then hold the box open side down just over the cluster of bees or rather touching the cluster. Now apply a little smoke to the bees from below. Much smoke should not be used. The bees will slowly crawl into the box. The box should not be moved while they are crawling into it. When all have got into it, it can be slowly removed but should not be turned over and should be held open side down as it was

presented to the bees. In this manner the swarm may be carried to any distance, provided all quick and jarring movements are avoided. It is better to cover the open side of the box with a piece of cloth while carrying the bees. Before trying to drive the swarm into the box in order to quiet the bees, sugar syrup may be sprinkled on them (not poured in large quantities). After waiting for a little while during which the bees will lick up the syrup and clean each other's bodies, the swarm can be driven into the box in the manner described. A swarm which has just emerged from a hive need not be treated to syrup as the bees fill themselves with honey just before issuing from the hive. On arriving at the place where the hive is to be kept, get a hive ready as described in (1), but putting in addition one or two combs filled with sugar syrup. (See page 57 on "Feeding.") The combs of sugar syrup should be placed near the entrance. If no empty combs are available the sugar syrup should be placed in a "feeder" above the quilt. The box with the bees may now be placed inside the hive, its open end turned towards the frames and touching the nearest one. The hive is now covered with the quilt and roof, and left. The bees will leave the box and occupy the frames. The box can be removed the next day and the frames closed up with the dummy. A newly-hived swarm should always be fed for some days. Then they are not likely to abscond and will build the combs very quickly. As a further inducement to stay, if there are other colonies going on, a comb with unsealed brood may be placed in the hive. The grubs will be taken care of by the bees which have an affection for nurselings, and they will not be left in an uncared-for state. The comb of brood should be placed near the box containing the swarm. If the box into which the swarm has been driven is too big to be accommodated in the hive, a gap may be produced in the hive by moving two or three frames towards the back and the whole swarm jerked into this gap by a sharp quick movement and the frames and dummy drawn forward and the hive at once closed with quilt and cover.

Sometimes the swarm settles at a place where it is not convenient to use box and smoke in the manner described. If it has settled on a branch the box may be held with the open side up just under it and the branch suddenly struck with a thick stick with such force as to dislodge the whole swarm into the box. The box is at once covered with a plank or cloth and turned upside down. The cluster will soon settle in the box and can then be hived. A wide-mouthed cloth bag can be used to catch a swarm which has settled on the branch of a tree. The open mouth can be passed up from below and closed over the cluster. The bees are carried to the hive and poured over the frames. If the mouth of the bag be not raised free from the frames the bees will not be able to fly.

When a swarm settles on a high inaccessible branch, a cloth bag can be used in the following manner. Its mouth is sewn round a loop of bamboo branch and the loop tied to the end of a pole. (Fig. 54.) The loop is

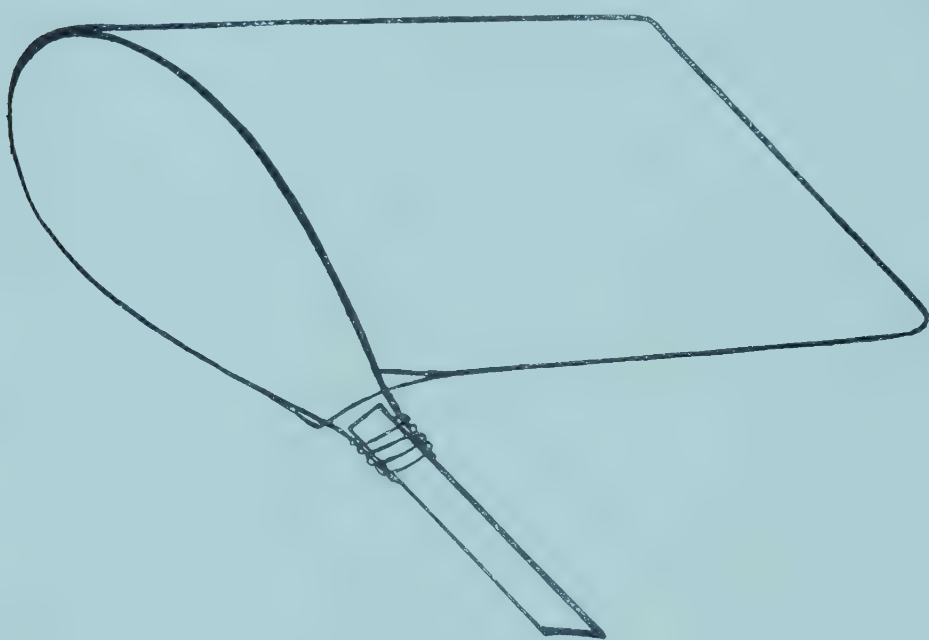

Fig. 54.—Swarm catching bag.

raised and made to touch the branch enclosing the swarm and then quickly drawn towards one side disengaging the swarm into the bag and the bag quickly turned edgewise preventing the bees from escaping.

General directions for capturing and hiving swarms are given above. On these principles judgment may be used as to how best it can be done by varying the conditions a little.

Sometimes when a swarm settles on a branch which can easily be cut, it can be carried home on the branch and hived directly. For this purpose the bees require to be gorged by continuing sprinkling them with sugar syrup for some time.

If use is made of bar-frame hives in which the body box is capable of being removed from the floor-board, swarms can be hived in the following manner, which is, however, not quite suitable for the Indian Bee, but does

well for the Italian Bee :—The front of the body box is slightly tilted up from the floor-board so as to present an entrance along the whole breadth of the hive. A plank or piece of cardboard is held just over the alighting board so that when the bees are poured on the board they can easily enter the hive. By a judicious application of smoke the bees can be made to enter the hive. Some of them may be pushed gently with the hand into the hive and the others will follow.

(3) When a colony has already settled and built combs in a place, the combs are cut out along the line of attachment and fixed into frames. For this purpose a comb-fixer is made with a stiff wire, as shown in Figure 55, by bending the ends of the wire at right angles and soldering cross pins to its body. Two of such wire-comb-fixers are fastened to each frame as shown in Figure 56. A comb is cut out and fastened into cross-pins of

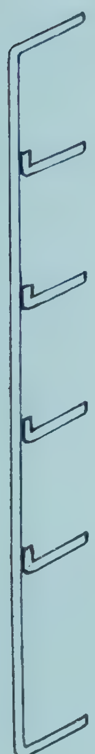

Fig. 55
Wire comb-fixer.

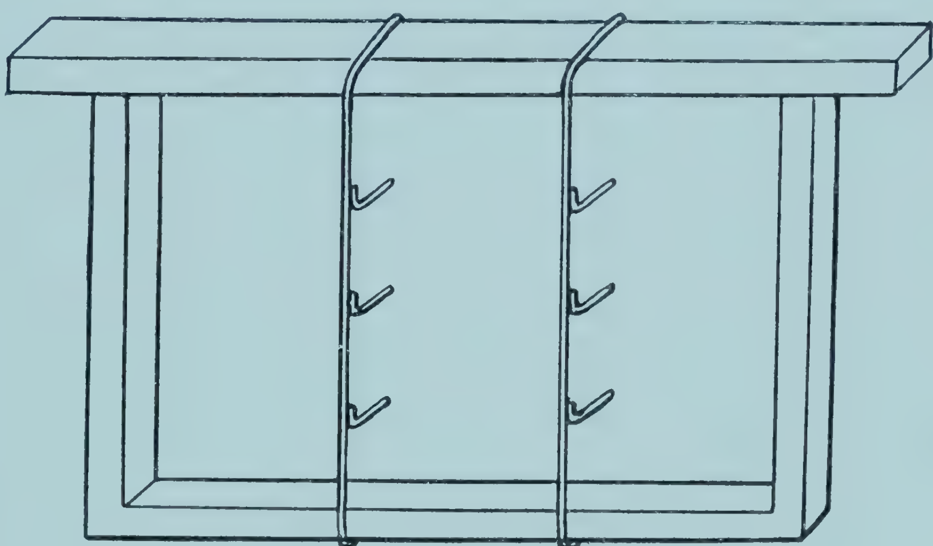

Fig. 56.—Frame fitted with wire comb-fixers.

comb-fixers, so that its upper edge touches the under-surface of the upper bar of the frame. If the upper edge of the comb is not straight, it can be levelled by cutting off a portion and then fixed into the frame. The bees soon fasten the comb to the lower surface of the upper bar of the frame with wax and the wire-comb-fixers can afterwards be removed.

When a colony has built combs in the cavity of a tree-trunk or wall, in the middle of a bright day when bees are flying freely, a wide opening

is made so that the combs may be cut out with the hands. Before this is done a hive is got ready as in (1) but without any starter of foundation in the frames which are now fitted with the wire comb-fixers. The bees are plentifully smoked before the operation is commenced. After the opening is made, by blowing smoke on them they can be made to leave the combs which can then be cut out one by one and fixed into frames and placed in the hive. The bees will cluster away from the combs. If there be space and convenience they can be driven into a box as in (2) and put in the hive. If this is not convenient the cluster can be scooped up with a bowl which is at once closed with a piece of plank and then inverted over the frames in the hive, the covering being slowly removed. The bees will crawl down and occupy the combs. The hive is now covered with its quilt and roof. The queen is sure to be brought into the hive with the cluster in this way. Some bees will remain inside the cavity. They can be smoked out or swept out with a feather. The cavity is now closed with mud entirely and the hive so placed that its entrance be near where the entrance of the cavity had been. The hive is left there till it is dark. The flying bees will enter it in time. The hive can be carried in the dark and placed in the permanent situation.

The transferring can also be done in the evening after darkness has set in. In the middle of the day many bees take wing and hover round the operator. At night the bees do not fly and therefore can be managed better. If it be not inconvenient the transferring is better done in darkness, of course use being made of light which is kept at some distance.

In the same way, bees from a log or box or pottery hives can be easily transferred into bar-frame hives. This is always better done in the middle of a bright day when bees are flying freely. For transferring from a log hive a sort of a box is necessary with one open side which will fit the opening on either end of the hive. First of all smoke is driven into the hive through one end and the hive removed to a little distance, the new frame hive being placed in its position. The log hive is turned over, tilted up a little and stood in a somewhat inclined position so that the combs attain a reversed position. Put in a little more smoke. After a little while place the box at the upper end which is now opened, and beat the sides of the log with two sticks. The bees will leave the combs and move upwards into the box and cluster in it. The cluster may be kept aside a little. The log hive is opened, the combs cut and fitted into frames by means of wire-comb-fixers and placed in the frame hive. The bees are then put in and the hive covered up with quilt and cover.

manipulations shown in Figure 59. A comb should never be held in a

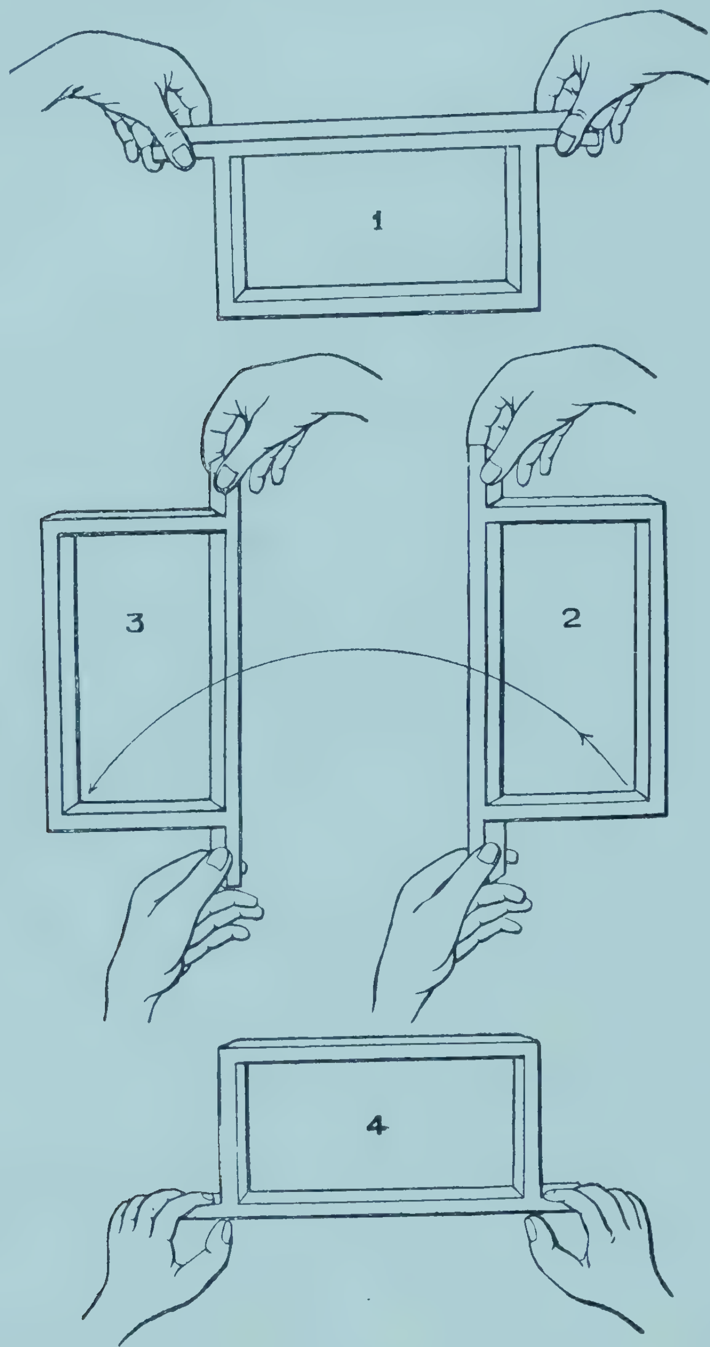

Fig. 59.—Manipulating a comb.

horizontal position, as when full of honey and brood it may break away. Position 1 in this figure is as it is taken out of the hive. Position 2 is obtained by raising one end. Then it is turned round (position 3) and the other side is in view. In order to be able to examine minutely the raised end is now lowered (position 4). By reversing the movements in order the comb is brought into the normal position and replaced in the hive. After examination all the combs and quilts are properly replaced and the hive covered.

Moving Bees.

Bees fly to a distance of about two miles or more all round from the hive and come back without fail. They take a careful note of the surroundings and remember the exact location of the hive. If the hive is removed the flying bees will come back to the place where it was standing and will hover in the air. They will fly round and round where the entrance of the removed hive had been and will ultimately drop down exhausted and die. If it is necessary to move a hive from one part of the apiary to another, it should be done gradually by about two feet and certainly never more than three feet every day. The moving should be done only at night after dusk when all bees have returned home. No moving should be done on any day on which the bees do not fly. In order further to make the bees note the changed surroundings some straw or grass may be thrown in front of the hive or a board like a signboard pitched in the front on one side. If however, it is intended to move a hive to a distance and to completely foreign surroundings it can be done on any day at night. If the hive is removed at once to a distance of two miles or more, not a single bee will be lost. If the distance is less than two miles, some bees while flying may get into the old run and return to the old location and thus be lost. The loss thus incurred is not however considerable and does not usually affect the population and strength of the hive especially if the new surroundings are quite different from and in contrast to the old. All take a note of the new surroundings and remember them, except probably some old bees.

Work of the Bees.

The routine work inside the hive may continue at night but outside fieldwork is done only during the day-time. All the bees of the colony return to the hive at dusk and stay in the hive at night. Bees fly most during the morning, less when it is hot in midday and again more in the afternoon. (N. B. Occasionally *Apis indica* comes in to light at night and perhaps occasionally these bees fly at night. T. B. F.) All return to the hive at dusk and remain there the whole of the night. They do not fly when it rains or when it is very cold and chilly or foggy.

Management.

The bees are kept in the hive well covered with one or more quilts to keep them warm. In the cold weather several folds of blanket may be necessary. In the hot weather a single piece of gunny cloth is enough.

The frames of the combs are kept at proper distances by means of the spacers. If they are left further apart extra combs may be built in the extra space. If the distance is less two frames may be joined by cross combs. The combs should be straight. If a comb is bent it should be straightened by pressure with hand and if this is not possible the bulging portion should be cut off. There should not be more combs in the hive than can be covered by the bees. The extra combs may be stored in properly closed boxes and given to the bees when necessary. All the combs should be pushed towards the entrance and if an open space is left inside the hive, the combs should be enclosed with a dummy behind.

Ordinarily the hive need not be opened every day for examining the bees. It is enough if it is opened and examined every 10 or 12 days to see (1) that the queen is there and laying eggs. It is not necessary to see the queen actually. If there are eggs and young brood, it can safely be taken for granted that she is alive and active; (2) that there is food for the bees, in the shape of sealed or unsealed honey; (3) that all the combs are covered by the bees; if not, take out the extra combs; (4) that Wax Moth or any other enemy has not got in. Combs which are not covered by the bees may be infested by the Wax Moth caterpillar. In the hive of the Indian Bee frequently debris collects on the bottom consisting of broken pieces of cappings, etc. Wax Moth caterpillars are frequently found present in this debris even though the combs are uninfested. Their presence is indicated by the webbing of wax and other particles into tubes. The debris should be cleared out, the caterpillars, if any present, should be killed, either cut with a knife or crushed under foot.

But a visit should be paid every day to the hive for a few minutes only. By a little experience the bee-keeper will find out whether matters with the bees are all correct or not, by simply looking at their behaviour. A visit in the morning will help to diagnose the condition of the colony almost as accurately as actual examination. On all bright days the bees should do field work, flying out and bringing in loads of pollen. The amount of field work varies according to season, more work being done in the season of honey-flow than at other times. If instead of working as usual the bees are found flying in front and round the hive as if seeking something, or listlessly sitting and hanging about the alighting board, there may be something wrong and an examination may be necessary.

The bees do little work in the rainy season as they find little forage outside. If no food is left in the hive, it may be necessary to feed them. Also they do hardly any work when it is very cold and at this time too they may require food. (See "Feeding" below.) When forage is short, breeding is carried on at a very slow rate, the queen laying a

small number of eggs and a small number of bees being reared. After the rainy season is over, breeding is resumed at an accelerated rate and it may be necessary to provide more combs in order to provide the queen with more laying space. The population of the colony will increase. When the combs in the hive are all covered by bees and filled with honey, brood and eggs, fresh combs can safely be added, being placed in the middle. By gradually providing more space the population of the colony should be increased as much as possible. The more populous a colony in the honey season the more honey it will gather, yielding greater surplus. When combs are not available, frames with full sheets of foundation should be supplied and combs will be built on them. It is only in the honey-flow season that combs can be got built by the bees. In the Hills the more important honey-flow occurs in October-November and the bees will gather enough honey to yield a surplus. In the Plains at this time there is a short minor honey-flow; the bees gather a little honey but not enough to yield a surplus. The main honey-flow occurs in the spring in the Plains and a second honey-flow at this time in the Hills, surplus honey being obtained in both localities. The surplus honey is taken out by the bee-keeper and represents his profits. The method of taking out the honey or "extracting" as it is called is described below on page 69. The bees continue to get some honey till the end of May or even the middle of June, but of course in less quantities than in spring. Breeding is also carried on at a maximum rate in the honey-flow season and decreases gradually. At this time the bees do not require so many combs in the hive. Therefore the surplus combs should be taken out and stored for use later on. If enough honey is left in the hive to serve as food for the bees till forage is available in the autumn, they will not require much attention.

Unless there be a source of water near the place where bees are kept, say, a pond or spring, water should be provided in a vessel which should be kept in a cool shaded place and it should be changed very often.

Feeding.

Bees do not require to be fed always, as they gather their own food, *viz.*, honey and pollen from plants so long as they are available. Even when honey and pollen become scarce in the fields it is not necessary to feed them so long as there is a store of these substances in the hive. Honey is the principal food of the adult bees and if there be no honey in the hive they will starve and it becomes necessary to supply food to prevent them from starving, in the shape of honey or honey diluted with water or sugarcandy

or sugar syrup. The feeding thus given may be called "starvation feeding." A starving colony may desert the hive and abscond. Pollen is the principal food of grubs and without pollen brood-rearing is not possible. Usually bees gather pollen even when the plants are not secreting nectar and it can be easily found out whether any pollen is being gathered by standing in front of the hive and watching the bees which are returning from the fields. Loads of pollen on the thighs of hind legs of returning bees are easily distinguishable. If no pollen is being brought in, and there be no store of pollen in the hive, it becomes necessary to supply a substance which may serve for pollen, so that brood-rearing may not be stopped. Any of the following can be used as a substitute for pollen, *viz.*, ground whole kernels of oats, corn and wheat, cotton seed meal, pea meal, wheat flour, rye flour, bean meal and barley meal. The common practice is to use rye meal or pea meal. The substitute has to be scattered on a board or on clean dustless ground in a cool shaded place near the hive and protected from rain. In India, at least in the Plains, bees gather pollen throughout the year, but get very little honey in the rainy season. Brood-rearing is not carried on satisfactorily on a large scale unless the bees get honey from outside sources, though there may be sufficient store in the hive itself. Therefore in the rainy season brood-rearing is at an ebb and all the pollen that is gathered is not used. For this reason a large quantity of pollen is found stored in the combs at this time. Food may be supplied to accelerate breeding and this is called "stimulative feeding."

As a rule it is better to do away with the necessity of feeding bees at any time. If after the honey-flow is over enough food is left in the hive it will not be necessary to feed the bees in the time of scarcity in the rainy season. A little stimulative feeding can be practised with profit in special circumstances. To take a concrete example, at Pusa a short minor honey-flow occurs just after the rains at the end of September or early in October. Breeding is accelerated by the bees at this time. Breeding is again retarded when this flow is over and resumed on a large scale by the middle or end of January when the main honey-flow commences. A little stimulative feeding may be given when the minor flow is over so that brood-rearing may be continued unchecked. This will be profitable because when the main honey-flow commences there will be a large body of workers ready to gather the honey as soon as it is available.

Discrimination should be used in supplying food, and when to supply it, has to be determined by the bee-keeper by examining the condition of the colony.

(1) Starvation food should not be supplied in large quantities, *i.e.*, approximately not more than what is required. If more is supplied all

combs will be filled with the surplus, leaving no room for the queen to lay eggs. Therefore brood-rearing may be seriously interfered with. Whether more is being supplied than necessary can be found out by examining the combs. If a large quantity is being stored the supply should be decreased.

(2) For stimulative feeding too the above applies. In addition stimulative feeding hardly serves the purpose when the colony is very weak in population and when the queen has ceased to be prolific. It serves the purpose well when the colony is fairly populous and possesses a prolific queen. Therefore if it is intended to apply stimulative feeding to a very weak colony, care should be taken to increase its population by the addition of sealed brood or bees from other colonies.

Food and how to give it.

The best food is honey. If there is capped honey in any comb, the capping may be scratched and the comb placed in the hive. The bees will utilize the honey. If there be any capped honey in the hive, the capping may be similarly scratched.

Extracted honey can be supplied diluted with water in the proportion of half water and half honey and warmed a little. Good cane sugar dissolved in water in the proportion of 1 lb. sugar in 1 pint water and warmed a little serves the purpose equally well. Fermented honey should not be fed, nor any honey of which the source is not known; because it my contain disease germs. If any purchased honey is used the solution should be boiled for about half an hour and should then be supplied when cooled. The liquid food is poured into an empty comb which is then placed in the hive.

Various kinds of feeders, *i.e.*, vessels in which to supply food, have been devised. Use of empty combs is the best as it places the food at once within the reach of the bees. Any flat bowl or tin pot can be used as feeder. The food is placed in the pot and some straw or sticks floated on the food so that the bees may find resting place or they get drowned in the food and die. The pot is placed on the frames. If its sides are smooth, some straw or sticks may be placed in a slanting position both inside and outside the pot so that the bees may easily walk over these supports and reach the food. A satisfactory feeder is made with a wide-mouthed bottle or glass or tin can. It is filled with food and its mouth tied with a piece

of cloth as shown in Figure 60a. It is quickly inverted and placed on the

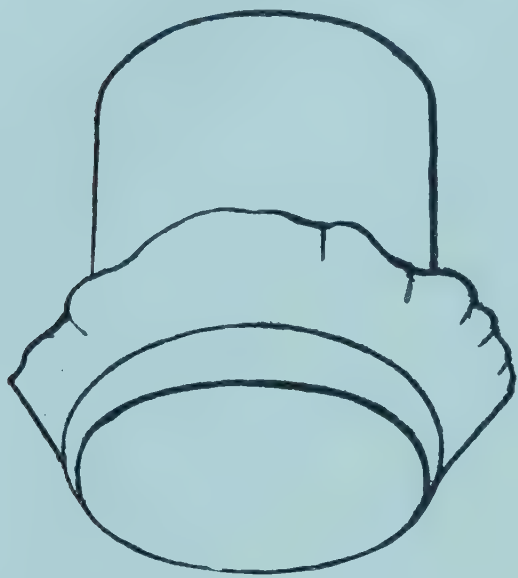

Fig. 60 a.—Tin can feeder.

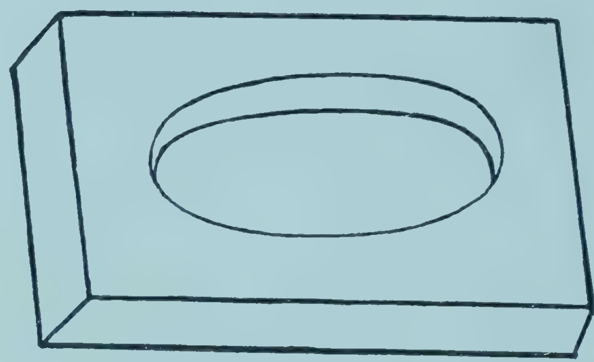

Fig. 60 b.—Wooden block for feeder.

frames mouth downwards. The bees suck out the food through the cloth. This does very well for stimulative feeding. In order further to secure and steady it on the frames a block of wood (Fig. 60 b) may be used, in which a hole is made to fit the mouth of the bottle. A very satisfactory feeder is made with a jam bottle having a screw top tin cover. A few big holes are cut in the tin cover. The bottle is filled with syrup, the cover put on and a piece of cloth tied over it. It is similarly placed inverted in a wooden block on the frames inside the hive. (Fig. 61.) When it is very cold and it is not advisable to remove the blanket, a hole may be cut in the blanket and the block of wood placed over this hole so that bees can take the food down without allowing any cold air into the hive.

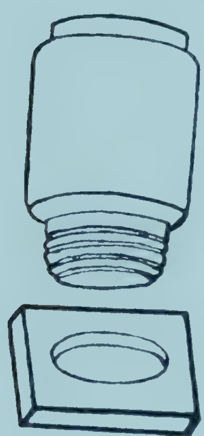

Fig. 61.
Bottle-feeder.

Robbing.

In times of scarcity when no honey is available from plants, bees try to rob each other. Usually weaker colonies are robbed by stronger ones. The bees force their way into the hive they rob, take the honey and store it in their own hive.

The surest preventive of robbing is to keep all colonies strong and to keep them provided with food. Starving bees make desperate attempts at entering other hives even though they may die in their attempt.

Robbing is excited if honey is allowed to be spilt or to remain exposed near the hives. Bees get into the bad habit of robbing when they get

honey so easily. In times of plenty they do not mind honey thus left exposed. For this reason in times of scarcity hives should be opened and closed as quickly as possible. It may be advisable to do away with the necessity of opening hives at all at this time. The smell of the honey in it may induce robbing. For the same reason it is advisable to supply food at dusk when bees have stopped flying, if any colony requires to be fed at all. In times of scarcity the entrance hole should be diminished so that bees may be better able to guard it against robbers.

The Indian Bee is specially prone to robbing when in want of food and if Italian bees are kept, it will be found always making desperate attempts at entering the hives of Italian bees in the rainy season and up to September.

How to take the Surplus Honey.

The surplus honey is taken in two ways. (1) It is allowed to be stored in ordinary combs and then extracted by means of an extractor as described below. The honey thus secured is called "extracted" honey. (2) The other method is to make the bees build small combs in special small frames, called "sections" (Fig. 62) and store the surplus honey in these small

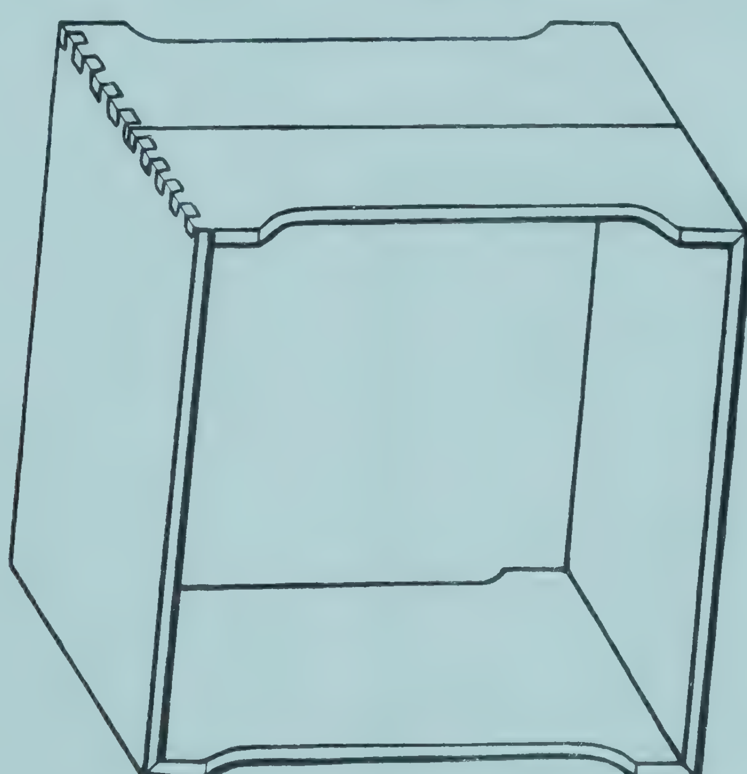

Fig. 62.—Section for comb honey.

combs. When the honey is capped, the section with the comb is sold, being enclosed in a glass case. The honey thus secured is known as "section" or more commonly "comb" honey.

It is more difficult to secure comb honey from the bees and comb honey cannot be produced unless the honey-flow is very rich and the bees are good gatherers. It is no use trying to secure comb honey from the Indian Bee. Even with the Italian Bee, the beginner is recommended to take only extracted honey.

Surplus honey from the Indian Bee.—As stated above only extracted honey should be taken from this bee. All that is necessary is a queen excluder dummy (Fig. 63) which is placed between the combs in order to partition off some of the combs from the queen. The queen having no access to them there will be no eggs laid in them and consequently no brood. Combs containing both honey and brood can be placed beyond the queen-excluder and when the bees have emerged the honey can be extracted.

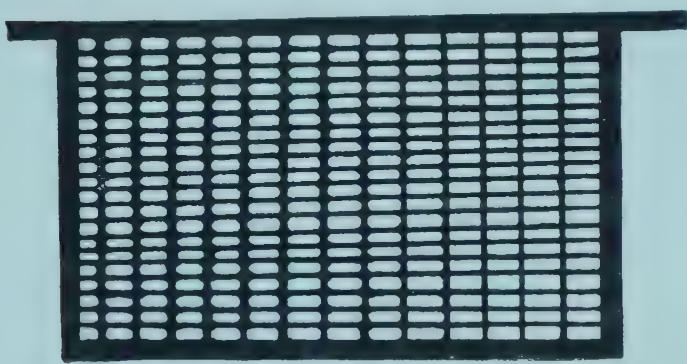

Fig. 63.—Queen-excluder dummy.

The kerosene-box hive is capable of accommodating 14 combs and the standard hive 12 combs for the Indian Bee. These combs are more than sufficient for a strong colony of this bee and in fact when it has attained to this strength, it is very likely to send out a swarm. Some of these combs are partitioned off with a queen-excluder dummy for storing honey to be extracted. No separate chamber or box is necessary for accommodating combs for surplus honey. In exceptional cases when it is necessary to find more accommodation, this can be done by adding another box above the hive in the manner described for the Italian Bee below.

Surplus honey from Italian or any variety of the European Bee.—Both extracted and comb honey can be secured from these bees. For extracted honey a box of the same construction as the body box of the hive but without the entrance hole, is placed above the body-box as shown in Figure 64.

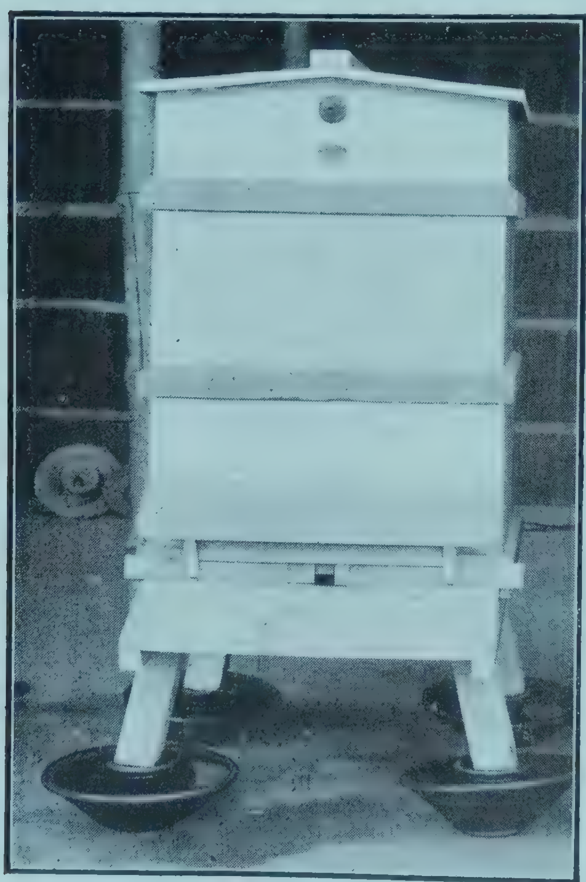

Fig. 64.—Hive with super on. Note how the size of entrance hole can be regulated by inserting two pieces of wood.

Figure 65 shows the parts of the same. A layer of combs is placed in

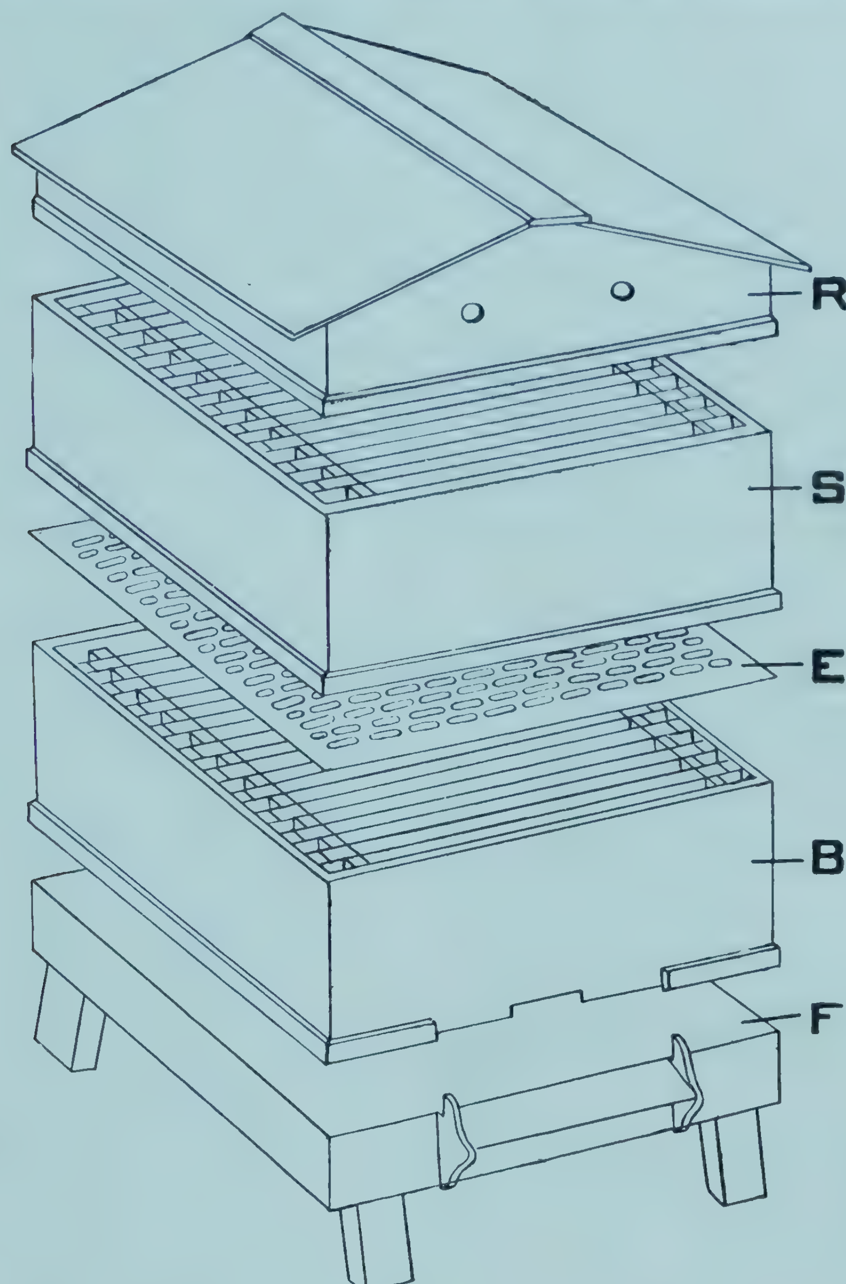

Fig. 65.—Hive fitted with super for extracted honey ; parts shown separately.
F.—Floor board.
B.—Body box.
E.—Queen-excluder sheet.
S.—Super.
R.—Roof.

the second box in the same way as in the body-box. This second box is known as a "super" or "doubling box." More than one super can be used, one above another, when large quantities of honey are being gathered. In order to prevent the queen from getting to the combs in the super and laying eggs in them, a queen-excluder zinc sheet is placed between the body-box and the super.

For comb honey, sections are required. They are sold in the form of flat pieces as shown in Figure 66 which is folded into the section shown in

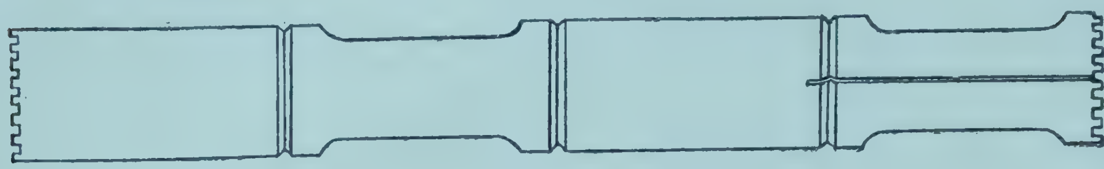

Fig. 66.—Section unfolded.

Figure 62. There is a slit at the upper side of the folded section into which is fitted a piece of thin comb foundation, specially manufactured for use in supers and hence called "super foundation," the foundation used in ordinary frames being distinguished as "brood foundation." The sections are arranged in a box, called a "Section Rack" (Figs. 67 and 68) open

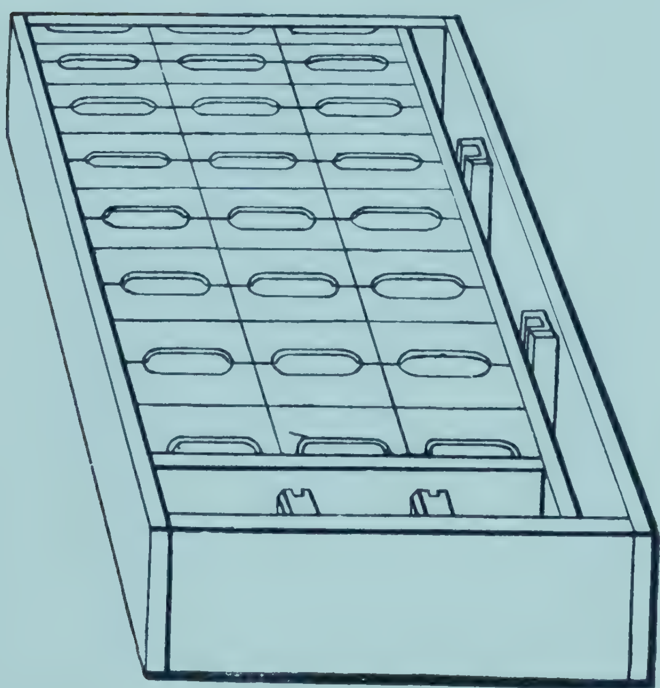

Fig. 67.—Section rack with sections arranged.

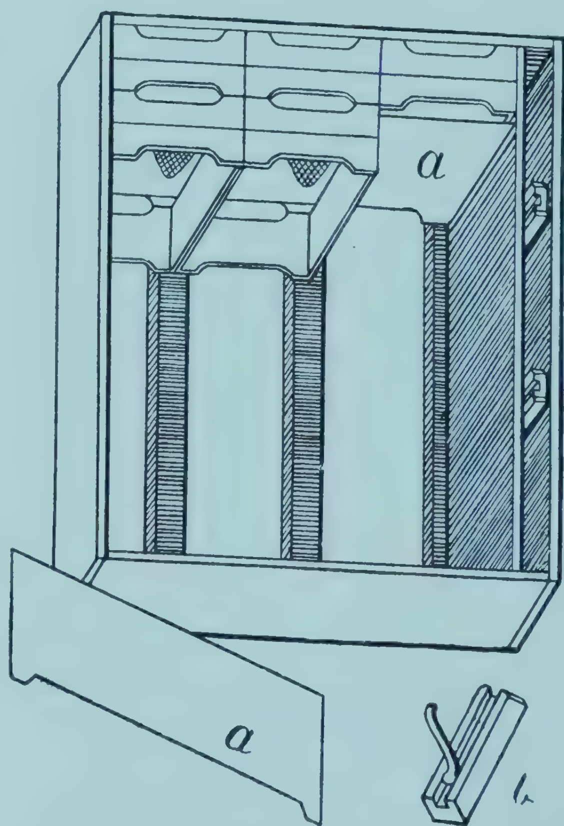

Fig. 68.—Section rack to show how sections are arranged.
(*a*) Tin divider. (*b*) Spring.

both at bottom and top and with only bars at the bottom for supporting the sections. A thin wooden or tin partition, called a "Divider" is used between the sections so that combs may be built separately in each. The sections are held tightly in the Rack by means of wooden boards and springs.

The Section Rack is placed inside a super as shown in Figure 69 with a

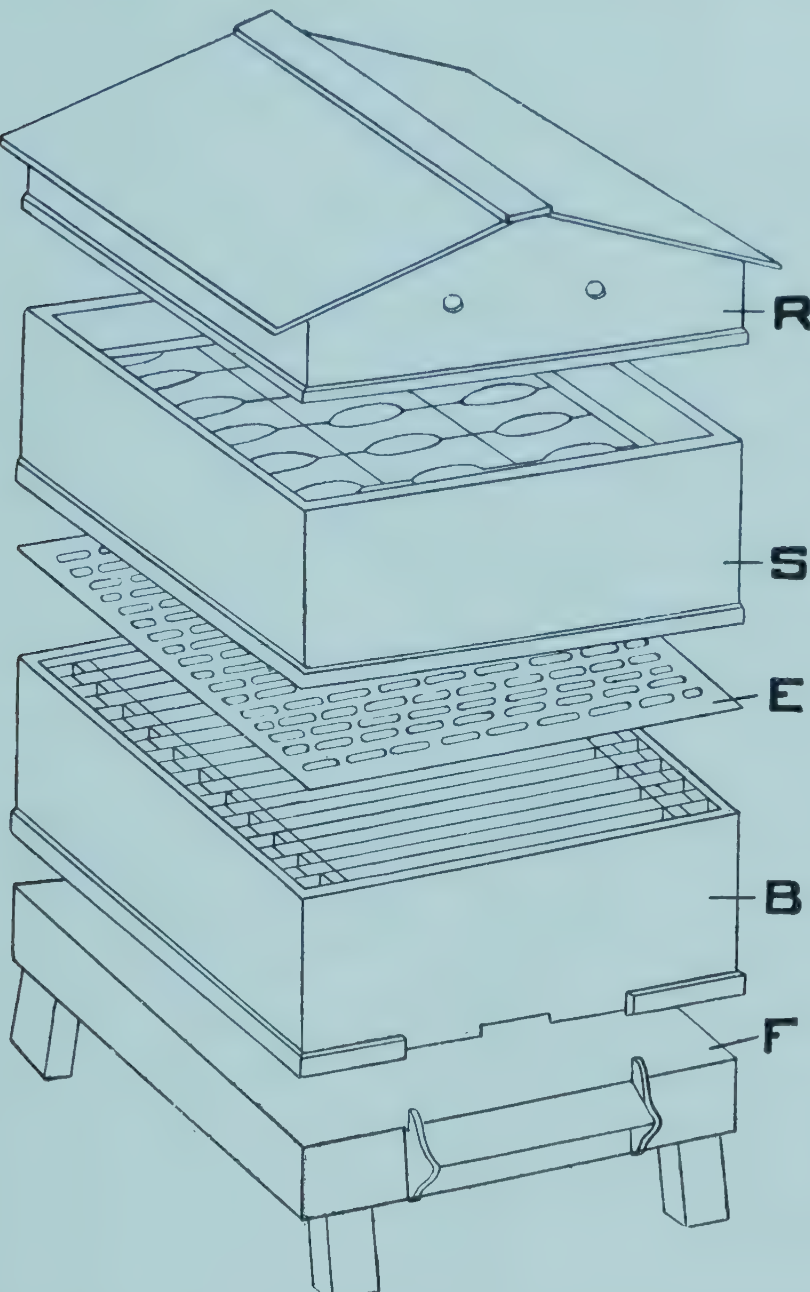

Fig. 69.—Hive with super arranged for comb honey ; parts shown separately.
S.—Super with section rack in place. Other letters as in Figure 65.

queen-excluder sheet below. In supers for accommodating Section Racks, the inside walls are dispensed with.

The upper chambers of the wall hive, which has been recommended to be made according to the measurements given, are for use as supers which can be utilized both for extracted and comb honey.

When the combs in the sections are filled with honey and capped and before the Rack is taken off, the bees are cleared off by using what is known

as a Super-clearer (Fig. 70). It is a flat board of the size of the bottom of the Rack and having in the middle a spring Bee-escape (Fig. 71) which allows bees to come out of the super but not to go back into it.

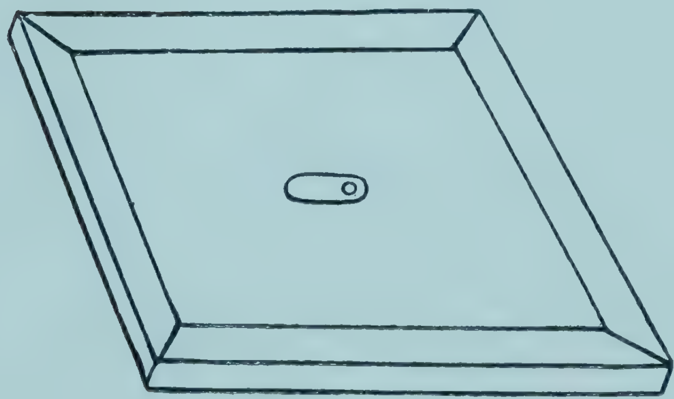

Fig. 70.—Super clearer.

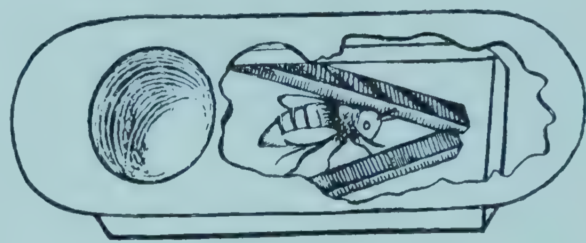

Fig. 71.—"Porter" spring bee-escape.

The Honey Extractor.

The Honey Extractor is a machine in which combs are rapidly revolved in such a way that the honey is thrown out of the cells and received in a vessel. The principle on which it works is this. If a weight is tied to the end of a string and rapidly whirled, there is a pull on the string and if the hold of the string is let go, the weight will fly off to a distance. This force is known as centrifugal force as the weight flies away from the centre of revolution. If a comb of honey is held with its surface at right angles to the centre of revolution and revolved, the honey of the outer cells will be thrown out, while the honey of the inner cells which face towards the centre of revolution will remain as it is, although these cells may be open, and will not be thrown out until the comb is turned so that these cells face away from the centre of revolution. On this principle many kinds of honey extractors are made and sold. They are of different capacities accommodating one or more than one comb to be extracted at a time. Each comb is protected by a wire-netting cage preventing the comb from breaking away from the frame.

While conducting the bee-keeping experiments at Pusa, a simple honey extractor * shown in Figure 72 was made. A A is a solid round iron rod

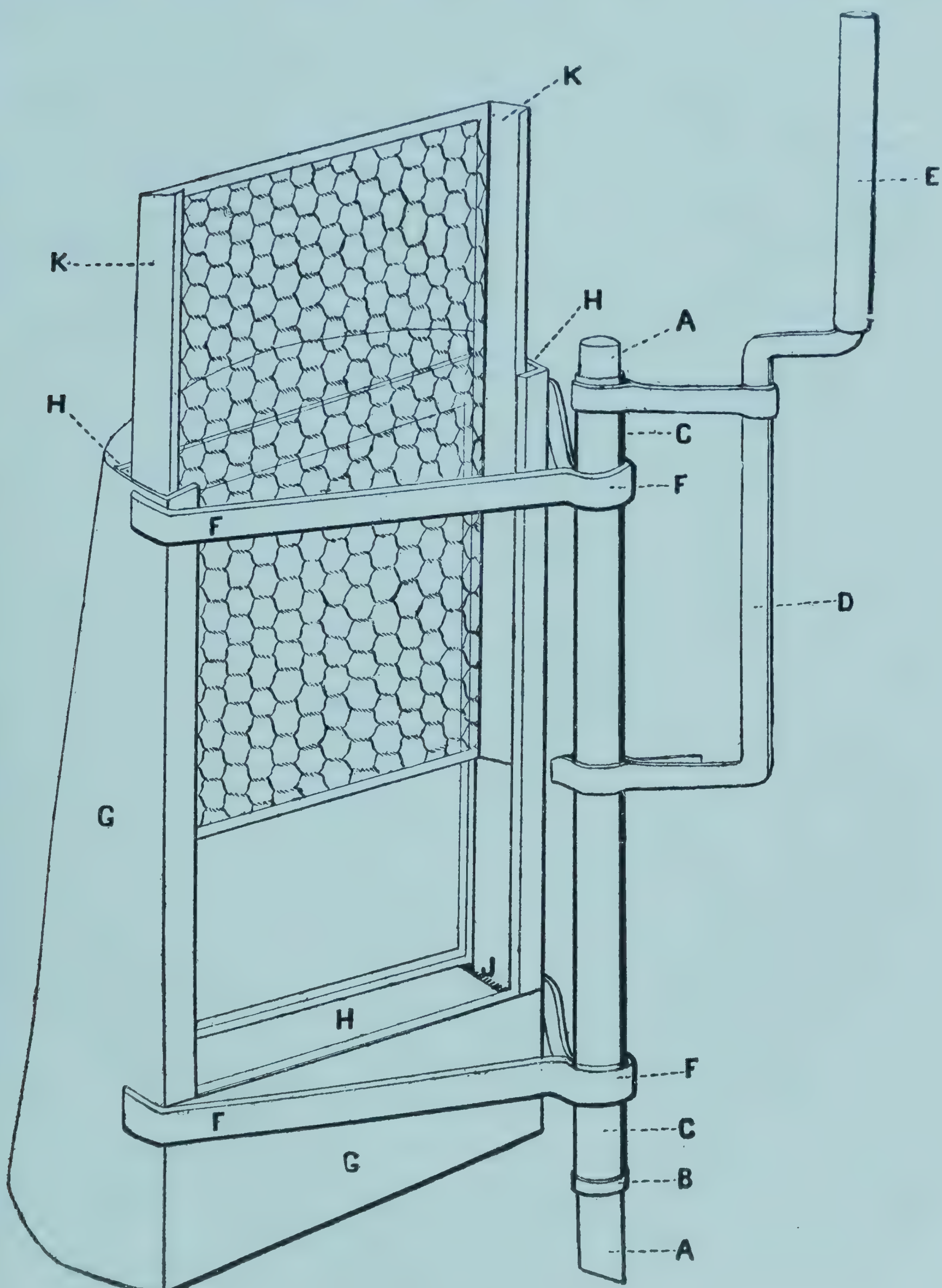

Fig. 72.
Honey Extractor.

*Daseribed in the *Agricultural Journal of India,* October, 1911.

pointed at the lower end for being driven into the ground. C C is a cylindrical iron tube which loosely fits over the rod, and is held at its upper part by means of the metal collar B soldered to the rod. To one side of C is rivetted the handle D and to its opposite side, two V-shaped arms F F which hold the honey-can G. The honey-can is made out of an ordinary kerosene tin. Inside the honey can there is a grooved wooden frame-work H, with a slot J at each extremity of the lower side to receive the projecting end of the frame of comb. K is the wire-netting comb-cage, shown drawn out. The comb is fitted into this cage and slid into the groove of H. In Figure 73 the comb is shown about half put in and the man is ready

Fig. 73.—Extracting honey. The comb has been slightly pulled out to show its position.

to revolve the machine. At E a piece of hollow bamboo loosely fits the handle and makes it easy to turn the machine. The comb-cage K is made of tin and galvanized wire-netting, the galvanizing of the netting being

carefully burnt off. No galvanized material should be allowed to come in contact with honey. The honey is thrown out and received into the can and then poured out.

Similarly a machine can easily be made to extract two or four combs at a time. A convenient one and much better than the above is shown in Figure 74. The comb-cages are fixed in a separate revolving part and there

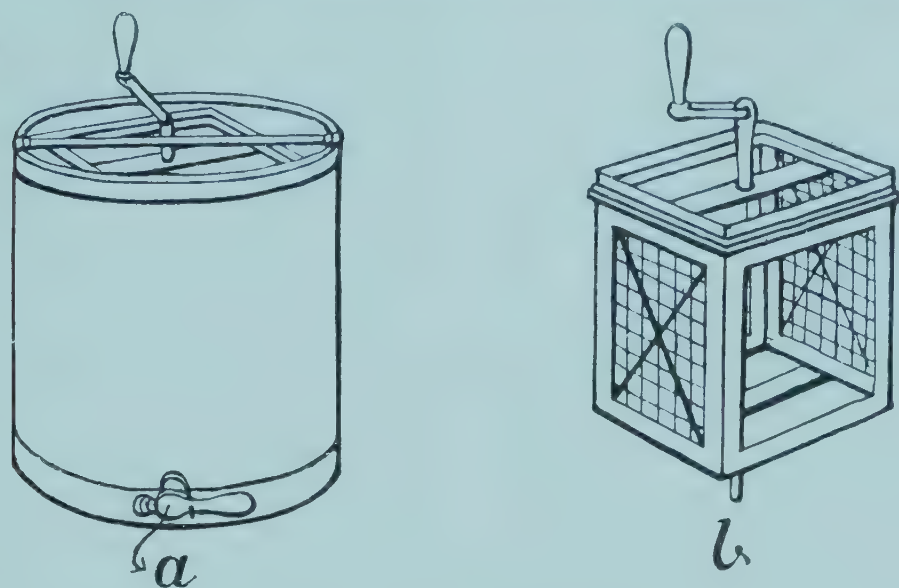

Fig. 74.—Cylinder Honey Extractor.
(*a*) Gate for drawing out the honey. (*b*) Revolving part with comb cages shown separately.

is a separate cylindrical drum in place of the fixed honey cans. The uncapped combs are simply stood against the wire-cloth walls and the machine revolved. This machine is an efficient extractor suitable for a tolerably large apiary. When making a machine the size of the comb-cage should be such as to receive a standard frame. Then the combs of the kerosene-box hive can also be extracted in the same machine.

Extraction of Honey.

After the honey cells are capped the comb is taken out and the bees brushed off from it back into the hive by means of a feather. The comb is then taken away and the honey cells opened. This is done as follows :— Two honey knives are placed in hot water so that the blades may be heated. The comb is held in the left hand in a vertical or rather slanting position and stood on a dish. The cappings are sliced off by passing the hot blade of the knife flat on the surface of the comb and just under the layer of the cappings. When one knife gets cool it is placed in the hot water and the other used. Both the surfaces of the comb are uncapped in this way. If the comb bulges out anywhere, as it frequently does in the upper part, the bulging portion should be cut off so as to make the surface of the comb

level. Then it is placed in the comb cage of the extractor. The extractor is revolved slowly at first and when about half the honey of one side has been extracted, the comb is turned so as to extract the honey of the other side. The extractor can be revolved with full force now and when this side has been extracted, the comb is turned back again to extract the honey left in the first side. When the comb is full of honey, the above method of extracting should be adopted. If revolved with full force from the beginning, the weight of the honey may break the comb. If, however, combs are not so heavy with honey, not being full of it, they can be revolved with force from the beginning. The comb will yet remain wet with honey after extraction and should be given back to the bees and will be soon licked dry by them. The honey is poured out of the can and strained through a muslin to remove broken pieces of cappings, etc. When a number of combs are extracted the cappings from them contain some quantity of honey. This honey can be got out from them in a pure condition if treated in the manner described in Appendix A.

Uncapping and extracting should be done in a closed place, for instance, inside a room. If done in an open place, bees will be attracted by the smell of the honey and will render the operation difficult. In the season of honey-flow when plenty of forage is available, bees may not be attracted, being busy with gathering honey. But during the period of decreased honey-flow or drought, bees are sure to be attracted and will come in numbers to rob the honey. All extraction should be done as the surplus is available. At least no extracting should be kept waiting to be done till the wet season. If left over till then, the honey will be of a deteriorated quality, as it rapidly absorbs moisture from the atmosphere and may ferment and become sour.

Also no combs should be stored away from the hive, which are not completely dry and empty. Combs containing pollen should be left with the bees. If there be any honey or pollen in the stored combs, both ferment and are attacked by a mould in the wet weather.

Ripening Honey.

As a rule the surplus honey should be extracted from the hive after it has been properly ripened by the bees themselves. This is indicated when the honey-cells are capped. Sometimes it becomes necessary to extract unripe or green honey in order to make room for more store. It can be ripened by the application of solar or artificial heat which will evaporate the excess of moisture. In places where the temperature in the hot weather goes beyond 100°F. ripening is easily done by leaving the honey for a few

days in a tin vessel in a warm place. The hot temperature evaporates the excess of moisture. This is more quickly done if the vessel is placed in the sun. When the sun is not available, artificial heat may be used. The vessel may be stood near the oven in the kitchen or better in hot water. Direct heat should never be applied to honey which should always be heated when necessary by being placed in hot water which again should not be allowed to boil. It is best to evaporate the moisture slowly by being kept in a hot water bath with a temperature of about 150°F. and never going beyond 160°F. Many kinds of honey ripening vessels, called "honey-ripeners" have been made and are sold. When large quantities of honey are dealt with, it is convenient to have one. A simple and efficient one is a tall cylindrical or square tin vessel with a closely fitting cover. If a tap is attached at the lower part for taking out the honey, it is very convenient and quite satisfactory and complete. The extracted honey is placed in it and allowed to settle. Particles of wax which may be in the honey and the thin honey rise to the top. The ripe honey can be extracted from below and bottled.

Conditions necessary for the production of Surplus Honey.

A colony of bees will yield surplus honey under the following conditions:—

(1) The colony must be populous so that there will be enough bees to gather honey. A weak colony may not yield any surplus at all.
(2) The plants must secrete enough nectar.
(3) The climatic conditions must be favourable for the bees to forage. Bees cannot work on chilly, windy or rainy days. On warm windy days they go out to work but many are lost, thus weakening the colony.

If all the above conditions are present, a colony will yield surplus honey and a variation of these conditions will cause a variation in the amount of the yield. Items (2) and (3) are not within the control of the bee-keeper. But he can manage to have strong colonies when the honey-flow comes on. Here a knowledge of the time when the honey-flow occurs is useful. We know that worker-bees are born in about three weeks from the time the eggs are laid and they go out to forage in about two weeks after their birth. Therefore brood-rearing should be pushed at least about a month before the commencement of the honey-flow, so that there may be enough workers present in the colony ready to gather the honey as soon as available. We also know that more brood is reared when the bees get honey and pollen from outside. Therefore if they do not rear more brood when it is desired,

they can be made to do so by giving them food, either honey or sugar-syrup and a substitute for pollen, either rye meal or wheat or oat meal. When it is not possible to strengthen colonies by stimulating breeding, two or more weak colonies may be united (see "Uniting") to make a strong one. When however the colony is thus made strong, the bee-keeper may be faced with one difficulty and that is, that the bees may like to swarm and baffle his efforts by thus dividing themselves and consequently weakening the colony. Therefore precautions must be taken to prevent swarming.

Uniting.

Uniting is joining two or more swarms or stocks into one. The swarms of the Indian Bee are usually small and when many are available they can be strengthened with advantage by two or three being united into one. The simplest way of uniting swarms is to hive them together in the same hive. If one swarm has already been hived, another captured in the course of the same day, may be put in the same hive after first of all smoking both. Similarly swarms which issue out of one's own stocks may be united. Out of two or three queens which may be put in with the swarms only one will be allowed to live.

Two weak stocks may be united to make a strong one. For this purpose the stocks should be moved towards each other (see "Moving Bees") until the hives are brought close to each other. Then on a bright day when bees are freely flying both the stocks are smoked well and the bees in both are sprinkled with syrup which is scented with peppermint. The peppermint will hide the distinctive smell of the two colonies. Only just so much peppermint should be used as will afford a smell. An excess of it has a choking effect. Cloves, aniseed or any other aromatic substance

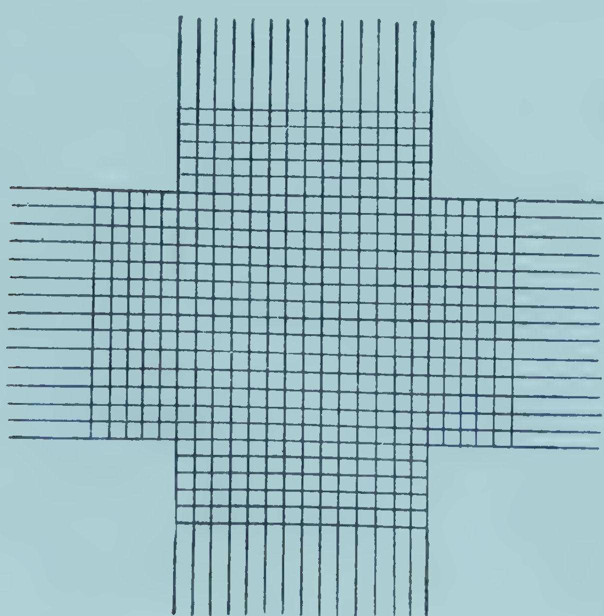

Fig. 75 *a*.—Queen cage.

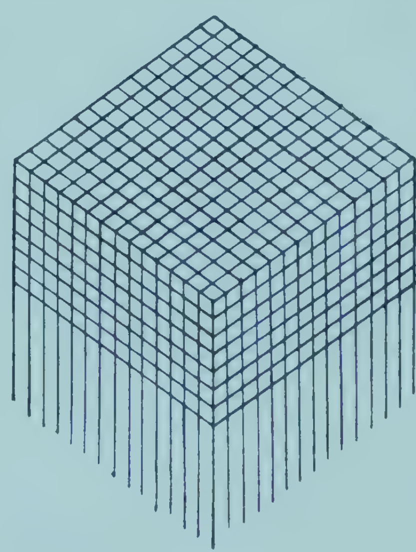

Fig. 75 *b*.—Queen cage.

may be used. Then the frames of combs from one are taken out and placed alternately with the combs in the other hive. The empty hive is removed and the occupied one placed in the intermediate position between where the two hives stood before uniting. The flying bees will come and enter this hive. Of the two queens only one will be allowed to live. If there be a choice between the two queens, the younger and better one may be protected by being confined in a queen-cage (Fig. 75) just before uniting. The other queen may]be utilized elsewhere if necessary.

The queen-cage.—A simple and satisfactory queen-cage is made with a piece of wire-gauze by cutting off pieces about $\frac{3}{4}$ inch square from its four corners and then bending the sides as shown in Figure 75. Some strands of wire are removed from all the four sides up to about half of the cut portions. When complete, the cage should measure about $1\frac{1}{4}''$ to $1\frac{1}{2}''$ each way and about $\frac{3}{4}$ inch deep. Another type of bigger cage is made in the same manner measuring about 4″ or 5″ in length, about 2″ in breadth and about $\frac{3}{4}$ inch deep. The wire-gauze with which these cages are made must have about 12 meshes to the linear inch. The queen is confined in this cage which is pressed into the comb up to about half its depth. She should better be confined towards the middle of a comb. The place where she is confined should have several cells of uncapped honey. If she has to be confined over capped honey, the honey-cells must be uncapped. If workers are just hatching out from a comb, the queen is better confined over the hatching bees with the bigger type cage with enough uncapped honey. If no hatching bees are available, the smaller type cage must be used. The hive is examined after about 24 hours and if the bees are hostile towards the queen, many walking over the cage rather angrily trying to sting her, she must be confined for another 24 hours. Then when they are reconciled to her, only a few sitting or walking slowly on the cage and smelling and caressing her, the cage is taken off.

When a stock becomes queenless through accident or death and if the bees have no opportunity of rearing queens to re-queen themselves and also there is no queen available to give them, the stock should be united with a queen-right colony. The queenless colony has to be moved to the queen-right one and then united, the queen being confined beforehand.

Prevention of Swarming.

Overheated and overcrowded bees are particularly prone to swarming. Therefore care should be taken to see that there are always enough empty combs for the queen to lay eggs and also for the bees to store honey. This can be secured by frequently extracting honey and adding more combs.

The hives should be shaded in the hottest part of the day and if necessary thick warm quilts may be dispensed with, keeping only a thin one so that there may be good ventilation. If many bees are found sitting near the entrance on the alighting board and vibrating their wings, arrangements should be made for proper ventilation. If enough space for the bees in the shape of combs is provided so that they may sit rather spread out, over-heating of the bees will be minimized.

The queen should be kept towards the back of the hive behind the queen-excluder division board and when the combs to which she has access, are filled, they should be transferred in front of the queen-excluder and replaced by empty ones. As soon as drones are found in the hive, the queen should be thus confined by the division board. If the brood becomes overcrowded, a condition which will not happen always and certainly never before about the middle of the honey-flow, some of it may be given to weaker colonies. This is done by simply lifting a comb from the hive, brushing off the adhering bees back into it and putting this comb in the middle of the combs in the weaker colony. This removal of brood, however, should be done judiciously so as not to take away so much as to weaken the colony. Bees die quickly and in large numbers in the busy season and therefore much brood is required to replace deaths.

The hives should be examined frequently, every five or six days, and all newly-commenced queen-cells should be destroyed. If queen-cells are destroyed when they are just commenced or contain only eggs or young grubs, this goes a great way in preventing swarming. When the queen-grubs mature their destruction has hardly any effect. In the case of the Indian Bee, when the reigning queen has been confined at the back of the hive with an excluder dummy, a new queen may be allowed to be reared. The new queen will not lead out any swarm. The two queens will live amicably one on each side of the dummy. It is an advantage as more brood will be reared. Some bees are, however, such determined swarmers that they are not satisfied without swarming. In this case artificial swarming may be resorted to. (For artificial swarming see "Increase of Colonies.")

Increase of Colonies.

If it is intended to increase the number of colonies, it can be done in two ways:—

(1) *Natural swarming*.—The bees are allowed to swarm and the swarm captured and hived in a new hive. When a swarm issues from a colony it usually settles in a neighbouring place, on a wall or on the branch of a tree or bush and remains there for about half an hour. Then the whole swarm takes to wing

again and flies away to the place they select as their permanent quarters. Therefore the swarm must be secured when it has settled and before it flies away to a distance, or it is lost. In order to prevent after-swarms the colony from which the swarm has issued or as it is called the "stock," must be watched and as soon as a new queen has emerged, the bees will demolish the other queen-cells if they do not like to swarm again. If however, the queen-cells are not demolished and if the new queen which has emerged seems to be a perfectly healthy one, that is, not maimed or otherwise defective, it is advisable to cut out all the remaining queen-cells and not to allow the bees to build any more. The new queen is fertilized in time and the colony goes on. Thus two colonies are obtained out of one. There are many drawbacks in natural swarming. It is necessary to keep a watch for the swarm and when it issues it must be attended to at the expense of other, probably more important work. There is thus every risk of the swarm being lost. Therefore all bee-keepers resort to artificial swarming.

(2) *Artificial swarming.*—Artificial or forced swarming is dividing the bees in a colony without allowing them to divide themselves by natural swarming. If there is only one colony this is better done when the bees are making preparations for swarming (see page 20), that is, when the colony is full and queens are being reared. But it can be done when the colony is full and plenty of forage available. Select a bright day when the oldest queen-grubs are about $\frac{1}{2}$ to $\frac{3}{4}$ grown. Have one hive ready with 4 or 5 frames with starters of foundation, a dummy and quilt. Go to the stock (or parent colony) in the middle of the day when the bees are flying. Take out the comb on which the queen is found and place it in the new hive. Now move the stock a little and place the new hive in its position. Take out some more combs from the stock and brush the bees from them into the new hive with a feather, replacing the combs in the stock. In this way about one-third of the bees found in the stock at the time may be brushed into the new hive. Then the stock should be removed to a distance of not less than six feet. The bees which are out in the fields will join the new hive. The bees in this hive may require to be fed and may be induced to build combs quickly if fed with sugar-syrup. It may do if two combs with honey have been put in from the stock. But care must be taken to see that

there are no queen-cells in the new hive. In the stock the bees will raise a queen. She will be fertilized in time and the colony will go on.

Thus two colonies are got out of one. This method of swarming is called "artificial" or "forced" or "shook" swarming or "dividing" bees. When there are more than one colony the results are more satisfactory if three colonies are made out of two. It is done in this way. Let the two stocks be numbered A and B, and the situations or stands they occupy as 1 and 2. To illustrate graphically, they are arranged thus :—

A stock	B stock
Stand No. 1	Stand No. 2

Swarm A and place A's swarm in stand No. 1. Move A stock to stand No. 2 and B stock to a new situation which is numbered 3. Therefore their position will be as follows :—

A's swarm	A stock	B stock
Stand No. 1	Stand No. 2	Stand No. 3

The flying bees of A stock will join A's swarm and those of B stock will join A stock. A stock is the only queenless colony and whether there are queen-cells already started in it or not, queens will be soon reared.

If it is intended to have four colonies out of two, after a few days but before any queen has been born in A stock, B may be swarmed and the colonies arranged in this way :—

A's swarm	B stock	B's swarm	A stock
Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 4

B stock taking the place of A stock which goes to a new situation No. 4. There will be a number of capped queen-cells in A stock. Two can be cut out and given to B stock. The queen-cells should be cut out with a portion of the comb so as not to injure the queen inside, and fixed into a comb by means of pins as shown in Figure 76. The bees will soon join it to the comb with wax.

Fig. 76.—Queen-cell removed and ready to be pinned.

There are other methods of increase but they are not suitable for a beginner.

Re-queening Colonies.

(See " Relative Importance of the different members of the Colony," page 14.) In order that the colony may continue, it is necessary to replace the queen when old by a young one.

The queen of the Italian (and all varieties of the European) Bee retains vigour for two years and requires to be replaced by a young queen in the third year. Young queens are available for sa le in countries where the Italian Bee is kept and in order to re-queen a colony, a young queen is purchased and introduced into the colony, the old queen being removed at the same time.

The queen of the Indian Bee too retains vigour for about two years. But these bees are very prone to swarming and when swarming takes place, the old queen goes out with the swarm and the stock is provided with a new queen every year. (See " Swarming, " page 20.) Colonies which are allowed to swarm will re-queen themselves in this manner.

If however the old queen is replaced by a young queen early in the honey-flow season every year, it will go a great way in preventing swarming and will also keep the colony in an efficient condition. Re-queening of the colonies of the Indian Bee can be effected easily in the following manner, whenever there are drones present to fertilize new queens. In the Hills as well as in the Plains drones are bred in October-November and again in February-April. Confine the reigning queen to two or three combs at the back of the hive by means of a queen-excluder dummy, taking care that there are worker eggs in the combs from which the queen is excluded. The bees will quickly rear a new queen from these eggs and when this new queen begins to lay eggs, the old queen can be removed.

Another way of re-queening is to swarm a colony artificially. (See " Artificial Swarming.") When the new queen in the swarm begins to lay eggs, the old queen in the stock is removed and the stock reunited with the swarm.

What to do when a colony loses its queen.

When a colony loses its queen, see whether there are worker eggs or very young worker-grubs in any comb in the colony. If there are, cut off portions of the comb just below these eggs and grubs at several places. It may do, if only holes about $1\frac{1}{2}$ inches in diameter are cut. The bees will build queen-cells over these eggs and grubs and rear queens and re-queen themselves. If there be no eggs or young grubs in this colony, a comb containing such eggs and grubs from another colony may be transferred to it and the comb treated as above. If there are capped queen-cells available from

any other colony, a capped queen-cell may be given. The queen-cell should not be given until about 48 hours after the queen is lost. Otherwise the bees will destroy the queen-cell and also the queen-pupa in it. Sometimes the queen-cells are destroyed though given after sufficiently long periods. The queen-cells may be protected by the queen-cage (Fig. 75) which should be removed after about 24 hours, by which time the queen-cell will have acquired the smell of the colony. But queen-cells of which the tip has been thinned and the queen is about to emerge, should be caged in such a way that the emerging queen has enough moving space. By giving capped queen-cells the bees are saved much time.

It must be remembered, however, that the above plan will succeed only if there are drones available to fertilize the new queen. If no drones are available it is no use trying to provide a new queen to the colony and the best alternative is to unite with another colony. If a fertilized laying queen is available, she may be given to the queenless colony. She can be introduced into the colony by means of the queen-cage (Fig. 75). She is placed in the queen-cage the open face of which is then covered with a piece of stiff paper. This face is placed on the comb at the place where it is meant to confine her and the paper slowly pulled away and the cage pressed. It is better to brush the bees off from this comb before this. After confining the queen the comb is reinserted in the hive. The queen is released after 24 or 48 hours when the bees are reconciled to her.

[Queens should never be handled, as rough or careless handling may so injure them as to render them unfit for successful egg-laying. If handling is unavoidable they should be picked up very gently by the wings; under no circumstances should they be caught or held by the body. Queens do not sting and can be picked up quite safely. T. B. F.]

Wax from Broken Combs and Cappings.

Discarded or broken combs, cappings and all odd bits of comb should not be wasted. They can be easily rendered into wax. Although the broken combs and cappings are not saleable the wax can be readily sold, fetching a price of about 12 annas per pound when clean. By the ordinary traders wax is judged by its colour and smell. The natural colour of wax is yellowish white and it has got a characteristic smell of its own. Therefore it should be prepared and preserved in a way that will not affect its natural colour and smell. The methods of preparation or rendering are described below. It should be preserved in a closed box so that Wax Moth may not affect it, without naphthaline, etc. which hide its natural smell. Cappings and bits of combs should be stored in a closed box so that they may not be

affected by the Wax Moth and rendered into wax when a large quantity is accumulated. In rendering wax, cappings and clean white new combs should be separated and rendered separately as they yield a larger quantity of wax with less trouble. Old black discarded combs, pollen-clogged combs and all combs which bees have used in rearing brood, should, before rendering, be cut into small pieces and soaked in water for about 24 hours, the water being frequently stirred and changed. The pollen and dirt will thus be removed.

The simplest way of rendering wax is to boil the cappings and combs with water in a tin or enamelled or earthen vessel. When the combs are melted, the water, while yet very hot, is strained through a cloth into another vessel in which it is left and allowed to cool. The cocoons, etc., which are known as slumgum, remain in the cloth. The wax, when the water cools down, collects at the top and solidifies as a cake. There is usually a little dirt at the undersurface of this cake and this can be scraped off with a knife. If there is too much dirt the cake is re-melted and the dirt which collects at the undersurface removed by scraping. The wax should not be boiled too much but only to the extent which is just sufficient to melt all the wax. It is better to bring the water to a boil and then put in the combs. Iron or zinc vessels should not be used. A kerosene tin does very well. The water used should be clean. If there is iron or lime in solution, the colour of the wax is affected. The colour of the wax is better if it can be melted in such a way that the heat of the fire does not come in direct contact with it. This can be done in the following manner: Water is boiled in a vessel, and the combs and cappings are placed in another vessel which is put over or in the boiling water. The hot water melts the wax which is therefore never over-heated. The melted liquefied wax is poured into a vessel with flaring sides and allowed to cool and solidify. The slumgum usually settles at the bottom and the liquefied wax can be slowly poured out. On this principle various kinds of wax-extractors are made and sold.

The solar heat is also used in rendering wax and will be found very useful especially in the Plains of India. The common type of Solar Wax Extractor is an oblong box with a glass cover. The inside is lined with tin. One end is raised so that the glass cover is sloping and faces the sun. The wax is melted by the sun's heat and runs down and collects at the lower end. In order to prevent the slumgum from running down to the wax, a wire-gauze partition is fixed some way from the lower end. The essential thing in a Solar Wax Extractor is that it should be perfectly air-tight so that the heated air may not escape. On this principle a handy

Solar Wax Extractor can be made in the following manner: An open-mouthed tin or enamelled vessel is embedded in dry saw-dust in a kerosene packing case and covered with a sheet of glass. The box is tilted up a little so as to face the sun. This conserves enough heat to melt the wax. A tin or enamelled bowl is placed inside the basin and a piece of cloth tied to its mouth. The combs are placed on this cloth. The melted wax strains through the cloth and collects in the bowl.

The wax rendered in a Solar Extractor is usually of a good quality. It is also very convenient to have a Solar Extractor. All odd bits of combs and cappings as they are obtained, are placed in the Extractor and the wax is rendered without any further trouble.

Protection against Enemies.

The creeping enemies such as ants, etc. are kept off easily by the ant-preventing device shown in Figure 29. These are earthenware vessels and can be easily and cheaply got made by local potters. They have to be kept filled with water. If one can afford one can have similar ant-preventers made of wood or metal. Care should be taken that mosquitos do not breed in the water by frequent change or by the addition of a little kerosene oil.

The Death's Head Moth is prevented from entering into the hive by using a piece of wood with indentations $\frac{3}{8}$ inch $\times$ $\frac{3}{8}$ inch as shown in Figure 77. This is placed in the entrance. The bees are not inconvenienced but the moths cannot enter the hive.

Fig. 77.—Death's Head Moth preventer.

Against wasps nothing very much can be done. They can be beaten to death by a broom as they come and hover in front of the hive. Some of them build hollow nests underground and if these nests can be traced, they can be destroyed in the following manner: At night the wasps are not active and do not leave the nest. A fire is made with charcoal in a small pot. The fire is placed near the entrance of the nest. The entrance hole should be widened a little if necessary. Now sulphur is placed in the fire and the hole of the nest with the fire is covered by a wide-mouthed vessel. The fumes will go into the nest and kill the wasps. It will be more effective if a little arsenic is mixed with the sulphur. Another method is to take a

brightly burning torch (using kerosene oil) and hold the torch at the entrance of the nest which is now opened. The wasps fly out and are burnt in the flames. Another method is to pour a little carbon bisulphide,* about $\frac{1}{4}$ to $\frac{1}{2}$ ounce on a little cotton lint and push this lint into the hole. After waiting for about a minute, apply a fire at the entrance from a distance, say using a live charcoal or burning candle at the end of a long stick. As soon as the fire is applied, there will be a small explosion and just at that time the entrance should be stopped by throwing a spadeful of earth on it.

The Wax Moth cannot be prevented from entering the hive at night. The Italian Bees protect their hive against this enemy successfully but the Indian Bee cannot. Hence when Italian Bees are kept, there is no trouble in the hive on this score. In the case of the Indian Bee, the hive should be frequently examined, the debris which collects on the bottom should be cleared and combs which are not covered by the bees should be taken out and stored elsewhere. Combs, which are covered by the bees, are not usually found to be attacked by the caterpillars. Probably for this reason queen-less colonies in which the bees dwindle away fall an easy victim to this enemy. If the combs are held against the light the galleries are easily visible and also the caterpillars themselves moving in the galleries. The caterpillars can be pulled out with a pair of narrow-pointed forceps and killed.

When the combs are stored, they are attacked by the Wax Moth caterpillars unless kept well protected in a closed box, into which Wax Moths cannot enter. Before the combs are stored, there may be eggs of Wax Moth in them and in that case all the combs in the store will be destroyed. The best and surest method of getting rid of Wax Moth is to fumigate the combs with carbon bisulphide after taking them out from the hive and before storing.

Fumigation is done as follows : The combs are placed inside an air-tight box ; small cracks may be stopped by pasting paper over them and the box thus made air-tight. Carbon bisulphide is poured out on some cotton lint which is then put inside the box and the box closed. Leave the box closed for 24 hours. Better place the box at a distance where there will be no possibility of light or fire coming near it. Then take out the combs and store them. Examine the combs once again after about six days and if any caterpillars are found, fumigate them again. After this no

* Carbon bisulphide is obtainable from dealers as a liquid in bottles. A bottle containing a pound costs Re. 1. It is a highly poisonous and highly inflammable substance. Its smell should be avoided and no kind of fire, *e.g.*, lighted cigar, live coal or burning lamp should be brought near it. It should be kept in a well-stoppered bottle provided with a glass stopper and the bottle should be kept under lock and key and in a cool place.

further attention will be necessary and the combs will keep well if kept in a dry place.

Wax Moth breeds profusely in wild combs, which have been deserted by bees. Therefore all such combs in the neighourhood should be searched out and either buried deep under the ground or burnt or melted into wax.

Care of Honey.

Honey should never be left exposed. Being hygroscopic in nature, it readily absorbs moisture from air and is sure to ferment and becomes sour later on even when covered afterwards on account of the excess of moisture. Properly stoppered glass or china or tin vessels keep it well. It should not be allowed to come in contact with zinc. It should not be stored in damp moist places but keeps best in dry warm rooms, even a temperature of 100° F. doing it no harm. Conditions which will keep salt well will keep honey well.

Granulation of Honey.

All good pure honey granulates in time and may become thick and solid. This is called candying. Sometimes candied honey is cut out in the form of bricks—known as " honey bricks " and sold wrapped in paper. Granulated honey may be liquefied by being placed in the sun or in a water-bath, the water being hot but not boiling. (See under " Ripening Honey. ") Sometimes only a part of the honey in a vessel will be found to have granulated, the remainder being in a liquid state. When this happens, the granulated portion should be liquefied and the whole mixed before taking out any honey from the vessel, because in such cases some constituents of the honey predominate in one part and some in the other.

Marketing Honey.

The best way of offering honey for sale is in small 1 lb. jam bottles with screw-top cover. It sells quickly when offered in small quantities, orders for large quantites being executed otherwise.

Moving Bees to Different Pastures.

The main honey-flow in the Hills occurs in October-November and that in the Plains in spring. The same bees may be made to gather honey in both the localities. For this purpose they have to be moved up to

the Hills in September and brought down to the Plains in December. This plan may give good results, as the colonies by being worked in a honey-flow in October-November will be in a good condition to gather the honey in the spring flow in the Plains. As some may adopt this recommendation, some directions seem to be necessary as regards the best method of transport. For this purpose travelling boxes are necessary which will allow of enough ventilation through all parts of the box. A simple but quite efficient travelling box is shown in Figure 78. The cover and bottom

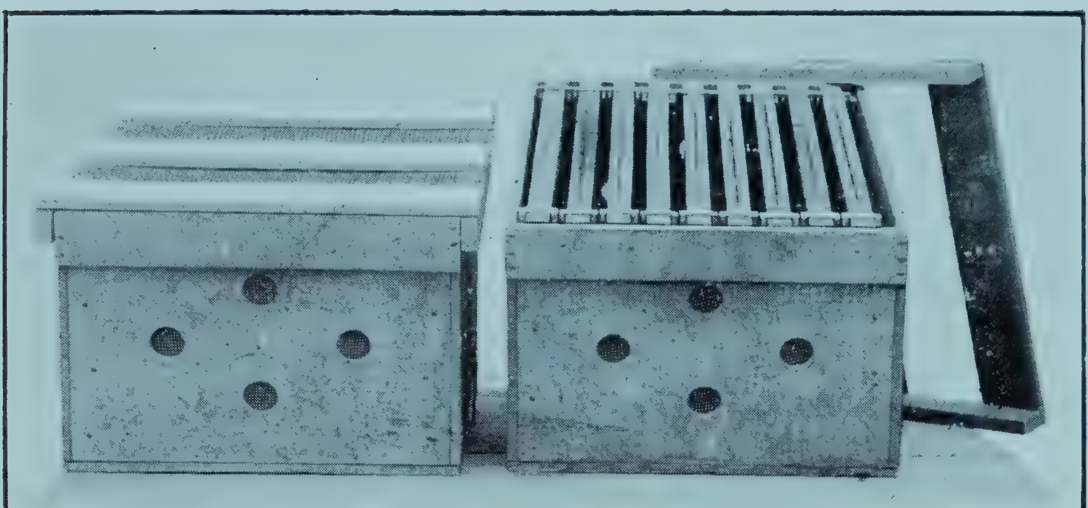

Fig. 78.—Travelling box.

are made entirely of a coarse wire-cloth with about eight meshes to the linear inch. A few holes protected by wire-cloth are also provided at the ends. The box is made of a size to receive frames of combs and when covered, the frames are held tightly in the place so as not to move or strike against one another in transit. If there is enough honey or sugar-syrup in the combs, the bees will travel well without any further attention The travelling boxes containing bees can be loaded one above another in a covered truck which will protect them from sun and rain but will allow sufficient ventilation. The boxes should not be exposed or left in the sun. The bees are transferred into travelling boxes after dusk when all flying bees have returned to the hive. The transferring is done by simply lifting the frames of combs with bees and placing them in the travelling box. If any bees sit on the sides of the hive they can be swept down on the frames. On arrival at the destination they are transferred into proper hives during the day time. When arrived at night the transferring should be deferred till the morning.

The Bee-Keeping Industry.

While it is not improbable that in time there will be bee-keepers in India who will own several hundred colonies of bees and make a living out of them, it must be noted that bee-keeping is best practised as a subsidiary industry. The reader should now be in a position to understand that the nature of the industry is such that it keeps a man engaged only for a part of the year, *viz.*, the season of the honey-flow and for some time preceding and following it. One cannot expect a steady income from bee-keeping because regard must be taken of bad years which will be poor in honey-flow and also of loss of bees through enemies or diseases.

The beginner should beware of embarking on a big scheme of bee-keeping all on a sudden, especially in an unknown locality. There is no means of testing the honey-yielding capacity of a locality except by keeping a few colonies of bees there. Although in India there are places, *e.g.*, the Hills, which are sure of yielding surplus honey, an ambitious scheme should not be undertaken without first of all gaining the experience and skill required to work bees. Bee-keeping is best started with a few colonies which may be increased as experience is gained. With experience a man can easily manage a few dozen colonies in his spare time and with the help of his domestic servants.

Appendix A.

How to extract honey from wild combs.

Good honey, which will keep for years, may be obtained from wild combs if extracted in the following manner instead of squeezing it out of the combs. The honey is stored in the comb in its upper part while the lower part contains brood. The part containing brood should be cut off and rejected. Then take off the capping of the honey by means of a broad bladed knife. If an extracting machine is available, the honey can be easily extracted in it. If no extracting machine is available, cut the comb containing honey into small pieces and place these pieces on a piece of muslin loosely tied over the mouth of a bowl or widemouthed clean earthen vessel as shown in Figure 79 and tie another piece of muslin tightly over the

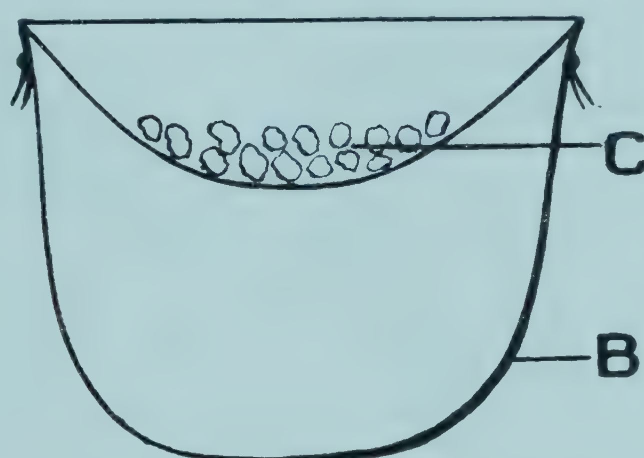

Fig. 79.—B.—Vessel. C.—Pieces of comb.

mouth of the vessel. This second muslin is to prevent bees from robbing the honey. Now place the vessel in the sun. The honey will ooze down quickly and can be at once bottled or otherwise taken care of as described in the book. The vessel can be placed inside a warm room or kitchen. But direct heat should not be applied as it may melt the combs. If done inside a room where bees may not have access, it can be managed in a much simpler way, the cut combs being placed inside a muslin and hung up somewhere and the honey allowed to drip in a vessel placed below. What is wanted is to see that the honey contains no foreign stuff, *e.g.*, pollen or juice of brood which should be scrupulously avoided and that the combs are not pressed. If done neatly in this way, the honey, that is obtained, is in no way inferior to that extracted in a proper extracting machine. (see "Care of Honey.")

Appendix B.

A note about appliances.

Of the various appliances described in the book, the following are necessary to make a beginning. Unless European Bees are kept, no other appliances are required :—

1. Hive. This can be made locally. A kerosene-box hive costs about Rs. 3. A well-made standard hive costs about Rs. 8.
2. Frames. One dozen for each hive. They can be made locally. Cost about Re. 1 per dozen.
3. Metal ends. One dozen for each hive. They have to be purchased ; cost about as. 3 to 6 per dozen.
4. Dummy or Division Board. One for each hive. It can be made locally ; cost about as. 3.
5. Queen-excluder dummy. One for each hive. It has to be purchased ; cost about Re. 1.
6. One Smoker. Has to be purchased ; cost about Rs. 2-8-0.
7. Ant-preventers. Four for each hive. Earthen ones can be had, made locally ; cost about as. 2 for four.
8. Quilts. One sheet of gunny cloth or *durry* and two sheets of blankets ; can be cut out from old rejected gunny bags and blankets , cost about as. 4.
9. Honey Knife. Two or one may do ; can be made locally ; cost about as. 3.
10. Wire comb-fixers. One or two dozen ; can be made locally ; cost about as. 6 per dozen.
11. Gloves. One pair ; to be purchased ; cost about Re. 1.
12. Veil. One ; can be made at home ; cost about as. 4.
13. *Matla.* Can be made locally , it is not necessary for those who wear hats ; cost about one anna.
14. Honey-extractor. One can be used by several bee-keepers. Although it can be made locally, it is better purchased. One can be had made for about Rs. 10. Good ones can be had for about Rs. 12 in England, which are sold in India for about Rs. 32. If there be a demand, the price will probably be lowered.
15. Comb foundation. One dozen sheets for each hive. All may not be used at first ; has to be purchased ; cost about Re. 1-8 per dozen sheets.

16. Tinned wire. Has to be purchased ; cost about as. 2 per small spool.
17. Wire embedder. One; a "pice" embedder can be made locally ; cost about one anna.
18. Embedding board. One can be made locally ; cost about as. 2.
19 Feeder. Bottle-feeder can easily be made ; cost about annas 2.

The above outfit costs about Rs. 22 with a kerosene-box hive and about Rs. 5 more with the standard hive. For learning the work, the beginner may commence with a kerosene-box hive and need concern himself with items 1 to 13 only and he can have about half a dozen frames which are ready fitted with wire and foundation. The cost will be about Rs. 11 or 12.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 47 1915

Agricultural Research Institute, Pusa

Notes on Sugar Machinery and Manufacture in Northern India, 1914

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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Notes on Sugar Machinery and Manufacture in Northern India, 1914.

Preliminary.

It is felt that the incompleteness of these notes requires some explanation.

Within a day of departure for Vancouver *viâ* the West India Islands, Colon and Panama, the writer was unexpectedly approached by the Harvey Engineering Company with a proposal to visit certain of the Sugar Districts of India.

The visit was to be made in place of Mr. James Harvey, the Managing Director of the Company, who was prevented by circumstances from leaving England, and its object as understood was to make calls upon the Agents of the Company and upon its clients, to ascertain the requirements of the latter in regard to sugar machinery, and to **advise the Government of India in connection with sugar matters generally** where such advice was desired.

Copies of recent letters which had passed between Mr. James Harvey and Mr. Bernard Coventry then in England on leave, in which the latter regretted his inability to see the writer before leaving, were found among the papers supplied by the Company, and the trip was entered on with but a vague notion of the importance of Mr. Coventry's position and in absolute ignorance of the conditions obtaining among the sugar factories subsequently visited.

The Harvey Engineering Company laid down no precise itinerary, but furnished the addresses of its Agents and of a number of its clients whom it was considered desirable to visit.

Before leaving London a call was made upon Mr. Francis Drake of the India Office, from whom it was ascertained that the Government of India had been apprised of the intended visit.

London was left on the 23rd January, 1914. On the 6th February on reaching Bombay and calling at the Secretariat it became evident that the Government of India had very much interested itself in the intended visit

of Mr. James Harvey, and that this interest had been extended to his substitute.

The Chief Secretary to the Government of Bombay, Revenue Department, had received from the Hon'ble Sir E. D. Maclagan, Secretary to the Government of India, Department of Revenue and Agriculture, a communication (No. 100-C., dated Delhi, 27th January 1914), referring to the subject. A copy of this with an original letter from Mr. F. Noyce, I.C.S., Under-Secretary to the Government of India, Department of Revenue and Agriculture, addressed to the writer and accompanied by a free-pass over the State-worked Indian Railways was received. This letter was also accompanied by a memorandum from the Hon'ble Mr. J. Mackenna, Officiating Agricultural Adviser to the Government of India, who had carefully considered and mapped out an extended tour with valuable advice as to how it was to be carried through. It was suggested that this tour should finish up at Poona under the direction of Mr. G. Keatinge, I.C.S., Director of Agriculture for the Bombay Presidency.

At the Secretariat I learned that Mr. Keatinge was momently expected in Bombay and, as I had made that gentleman's acquaintance in 1908, I deferred my departure from Bombay until I had seen him and ascertained that sugar conditions in the Bombay Presidency had not greatly changed in the past six years.

Mr. Keatinge was then on the way to Gujarat and it was arranged that I should visit Poona some time in March.

On February 11th I left Bombay, reaching Cawnpore on 12th, and on 13th called on The Harvey Engineering Co.'s Agents. These gentlemen were also understood to be agents—or part owners—of the Sugar Factories at Barak, Mahrourah, and Ryam.

The last-named was understood to be in process of erection.

Messrs. Harvey's Agents did not favour me with an invitation to visit either of these factories, but suggested a visit to Pilibhit—a factory with which they were in no way connected.

Mr. Mackenna had given the names and addresses of six of the Provincial Directors of Agriculture as gentlemen likely to facilitate enquiries during this tour. Among these were the Hon'ble Mr. H. R. C. Hailey, Director of Land Records and Agriculture for the United Provinces. Mr. Mackenna had suggested that a visit to Pusa should be deferred until after the return from leave of Mr. Coventry, Agricultural Adviser to the Government of India. Mr. Coventry was not due at Pusa until the 22nd of February. In order to obtain an authorisation to visit

the factory at Pilibhit therefore, it became necessary to find or to get into communication with Mr. Hailey.

Enquiries at Lucknow on the 14th February resulted in the information that he had gone to Pilibhit with the Lieutenant-Governor, was moving round, and likely to be at Aligarh on the 20th. On the 18th February a visit was paid to the Rosa Factory, and I left Bareilly *en route* for Aligarh on the 19th—20th but Mr. Hailey could not be found there.

As valuable time was slipping an unauthorised visit to Pilibhit was then decided on and made on the 22nd, when the native staff of the factory received me with the utmost courtesy and readily gave all the information asked for.

In returning from Pilibhit to Bareilly I had the good fortune to find in the train Mr. Hulme, of whom I had heard, but of whose precise position I had not been made fully acquainted. From that time until we parted on the 24th Mr. Hulme was unremitting in his kind attentions.

Late on the 23rd of February Mr. Hailey arrived at Aligarh and next day accompanied by him and Mr. Hulme I was privileged to visit the Experimental Farm at Nawabgunj.

Pusa was reached on the 26th of February where I had a most kind reception from Mr. Coventry who proposed accompanying me among the Bihar Factories, but as he was not then prepared to start out I paid a visit to Calcutta where on the 2nd March Mr. Nöel Paton, Director-General of Commercial Intelligence, was interviewed.

Some few years ago when favoured by this gentleman with some correspondence on the subject of central sugar areas, I had laid stress on the risk attaching to placing orders for complete sugar factories unreservedly in the hands of Contracting Engineers. Mr. Nöel Paton had not forgotten this, but at the time of my visit I was not aware how completely these remarks had already been justified in India itself.

On the 3rd of March I returned to Pusa and on the 4th Mr. Coventry took me under his protection and accompanied me for the next seven days through the Bihar Districts among the sugar factories.

During the course of that time the factories visited were :—

Bhicanpore, Barah, Seeraha, Pursa, Pertabpore and Bubnowlie.

It had been proposed to visit one other factory but the permission to visit it was accompanied by certain conditions and restrictions which, speaking for myself, I considered unnecessary. We did not, therefore, visit that factory.

On the 14th March I returned to Calcutta whence, on the 18th, I moved on to Delhi for the purpose of seeing Sir Robert Carlyle whose

acquaintance I had been fortunate enough to make in journeying between Calcutta and Waini in 1908.

Delhi was reached on the 20th and, after an exceedingly agreeable and interesting interview with Sir Robert Carlyle, was left on 21st for Madras *viâ* Manmad and Dhond.

From Madras, Poona was reached on the 26th March and after another interview with Mr. Keatinge I arrived at Bombay on the 29th. This completed the round, and it will be seen that the time spent in the sugar factories was too short to permit of more than a mere cursory examination.

That time was however long enough to produce the impressions which are here recorded as referring to the factories collectively.

Buildings.

Construction and Suitability.

The buildings seem to be solidly constructed but are in most cases insufficiently lighted. To this there is one notable exception, an exception also in the matter of space which, in most, is deficient.

Deficient space means insufficient lighting, and insufficient lighting makes cleanliness the first essential in a sugar factory—impossible.

The Approaches and Exits seemed, in most cases, ill-arranged resulting in confusion of carts and animals, a confusion in no way lessened by the scales in use. In one factory the canes were weighed on one scale and the cart, after searching round for a convenient spot on which to discharge its load was tared on another. Accumulations of cane in the yard prevented free manœuvring of carts and rendered impossible the grinding of cane in the order of its arrival, causing difficulty in cane carrier feeding and deterioration in cane seriously affecting the clarification of the juice and the quality and extraction of sugar.

Where central factories have encouraged small growers they have had great difficulty in controlling their deliveries. When growing canes for a factory of any considerable size the delivery is generally to some field scale where the load of the cart is picked up by a derrick and swung into the trucks of the factory. This is done while both cart and animals stand on the scale. After raising the load, cart and animals are tared and are free to move off. This system cannot, of course, be used in small factories

having no railways. The result of the want of control of the small grower may be seen in Figures No. 1 and No. 2.

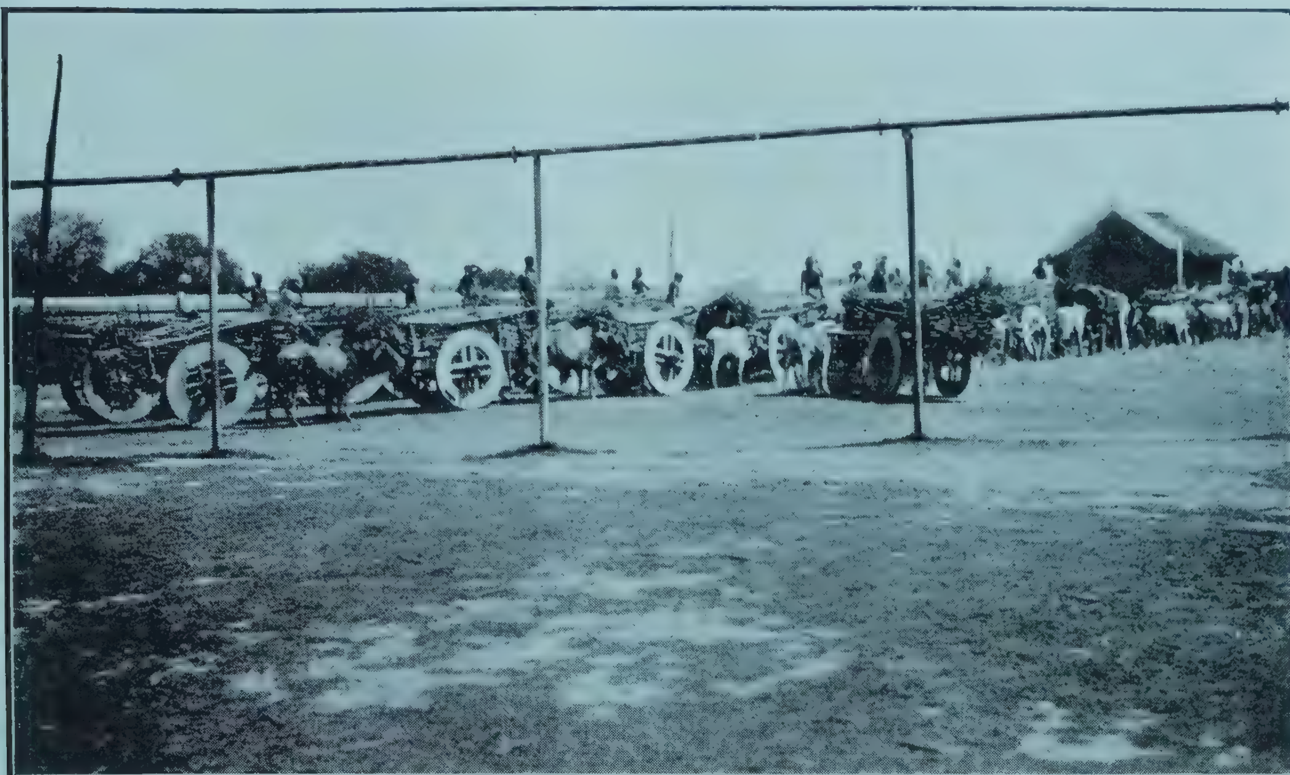

Fig. 1.—Block of cane carts and holding up of men and animals at an Indian Sugar Factory in March, 1914.

Fig. 2.—Showing in the background an accumulation of canes and in the foreground a hold up of men and animals.

Cane Carrier Feeding.

In all the factories visited this was done by hand and it appeared to absorb a great deal of labour. Mechanical feeding is a contrivance not yet 17 years old. It was first adopted on the Willswood Plantation, Louisiana, and was the invention of Mr. James Mallon, an American Engineer. The Mallon machine was a pronounced success. The second and third pairs of machines, built by the Bodley Wagon Co. of Staunton, Virginia, were erected at the Usine Ste. Madelaine, Trinidad, where they dispensed with 64 hands, dealt easily with the 1,700 to 1,800 tons of cane ground daily and could have disposed of five times the quantity.

Apart from the liberation of this large amount of labour for productive work in the field, other great advantages resulted from the use of these machines. The mills took the machine-fed canes more readily, and got through considerably more work with improved crushing.

The appearance of the Bodley Mallon rakes conferring as they did enormous advantages from an economic point of view and easing the work of supervision in the factory to an extent which can be appreciated only by those conversant with the working of cane sugar factories with tropical labour, was quickly followed by a number of other contrivances more or less widely advertised and different in efficiency, but all great labour-savers and infinitely preferable to feeding by hand.

Plate I (see at the end of the Bullettin) shows two pairs of Bodley Mallon machinesat work in 1899 in a factory dealing with 1,700 to 1,800 tons of cane per day.

Plate II (see at the end of the Bulletin) gives another view of one pair of these machines in full work in the same factory in that year.

The Gregg Cane unloader is a modification of the Bodley Mallon and has been well spoken of.

The Wicks works somewhat differently but is an effective machine. Plate III (see at the end of the Bulletin), Figure 1 gives a view of one at work in a Mexican sugar factory and feeding 800 tons of cane per day, but capable of doing much more.

This machine requires the attention of three hands. One attaches and releases the rope pulling the trucks up to the machine, one attends to the truck doors and one drives the engine. The two boys seen in the centre of the picture are not employed about the machine. The loaded trucks being pulled up to within reach of the claw push the empties to a point where they can be coupled up to the locomotive. The yard of the Trinidad Factory is graded 1 in 125—see Plate I—from the cane siding limit to the machines, and a touch of the hand brings the trucks within reach of the rakes. When emptied they move away slowly by gravity and

are collected by locomotives at the other end of the factory. This, however, is the case with the two outside lines only. The lines inside the cane carrier terminate in turntables on which the empties are turned out to be picked up and removed by the yard locomotive. Plate 1 shows all the hands employed to attend the emptying of 4 trucks simultaneously—except two bringing the loaded trucks down to the rakes and letting down the doors. The doors are put up by the train attendants at the other end of the factory.

In one Mexican factory the loads of the field trucks after passing over the scale are transferred by an overhead travelling crane to trucks of twice or three times the capacity. The latter are then drawn alongside the cane carrier to be emptied by hand while the small truck returns free to the field. The only advantage in this arrangement lies in permitting the work to be done with a smaller number of field trucks than what in the ordinary course would be necessary.

Plate III, Figure 2 shows the transfer crane, the empty small trucks passing out to the field, and the large trucks being emptied by hand under the cane carrier shed.

Figure 3 below shows transferred cane in the larger truck. Canes in this part of Mexico are cut into lengths of two feet to the benefit of the mill extraction.

Fig. 3.—Showing transferred cane in the larger truck.

The Link Belt Engineering Co. of New York have devised an overhead crane and sling for transferring bodily the contents of the small field truck to a hopper at the end of the Cane Carrier.

An idea of how this works may be gathered from Plate IV (see at the end of the Bulletin), Figures 1 and 2 giving different views of it. This machine is worked electrically as is the whole of the machinery in this factory except the mills, power being obtained from a stream behind the works.

The dumping of quantities of cane, weighing generally from one to two tons, in a heap on the cane carrier is highly objectionable.

A different plan for hopper feeding is in use in a French Factory in Tropical Mexico. The cane trucks are led on to a platform which is tipped by hydraulic power to an angle sufficient to throw off only a part of the load. As this is drawn away by the cane carrier the platform is further inclined and the struck gradually relieved of its load.

Fig. 4.—Bascule in a French Factory tipping a truck of cane into the carrier (wooden truck).

In a sugar factory in the Island of Antigua, West Indies, a tipping platform has been arranged to facilitate the feeding of the cane carrier. Over this the trucks are drawn and the canes disposed of by hand. Figure 6 shows this arrangement at work.

The factories visited in India have no railways of their own.

Fig. 5.—Truck relieved of its load. (Iron truck.)

Fig. 6.—Trucks being discharged into cane carrier from Railway Sidings crossing it.

Neither of the appliances mentioned can therefore be expected in any way to benefit them. All are inapplicable. But the American Hoist and Derrick Co. have a machine which, if it does not entirely eliminate labour at the cane carrier, will very greatly reduce it and can be depended on to keep the cane yard well regulated and to eliminate absolutely the blocks and delays to the men and animals engaged in the transport service.

Plate V (see at the end of the Bulletin), Figure 1 shows this machine swinging a truck load of canes, weighing from 1½ to 2 tons on to a sloping platform at the end of the cane carrier whence it is dragged by hand as it is required by the moving carrier.

Plate V, Figure 2 gives another view of the Derrick swinging a load into place where it can be reached by the four men occupied in feeding the cane carrier.

Here may be seen the head man and all the hands employed in the cane yard of this factory where 400 to 500 tons were disposed of daily. Beyond the line of trucks from which the Derrick is working may be seen a quantity of stored cane, to be used in the intervals between trains from the field, and at night when trains are not running.

Without modification the Indian cart would admirably lend itself to working in with such a machine and the mere saving of labour would be the very least of the advantages which would accrue from its adoption.

Questions as to juice extraction by mills did not result in much information which could be considered of value. In some of the factories, owing to the tangle of canes in the yard, the crushing cannot be taken daily—a serious drawback, as here no pains should be spared to obtain the maximum extraction.

In each case, however, the mills seemed to have fallen into careful hands. As far as could be judged by the eye all were doing good work. And this, in more than one case, despite the drawback of intermediate carriers scraping the bagasse from the first mill and presenting it in uneven quantity to the second.

In one case the crushing figures from the start of the crop of 1914 to the 28th February, week by week, were furnished by the Administration. The average fibre content of the cane during this period was given at 14·6 per cent. and the average crushing for the ten weeks works out at 62·69 per cent. On paper this does not look particularly good crushing. It is not while members of the staff are hovering round the cane carriers and watching the feeding of the mills in the full light of day that bad crushing is done.

Much might be said on this subject. Before leaving India, by the courtesy of Mr. Keatinge, Director of Agriculture for the Bombay Presidency, I became possessed of a copy of Bulletin No. 52 of 1912, Department of Agriculture, Bombay.

In that publication the author, Mr. G. N. Sahasrabuddhe, L.Ag., at page 12, gives a table constructed by my friend Dr. Watts of the Imperial Department of Agriculture for the West Indies, giving the possible juice extraction from 100 of cane with fibre contents ranging from 8 to 16 per cent. by mills varying from the poorest type of bullock mill to the 9 roller modern mill preceded by a Krajewski crusher.

These figures are no doubt very useful as approximations, but those referring to two three-roller mills strike me as low. In 1882, along with the late Alfred Fryer, well known in sugar circles in connection with the Concretor, I made certain experiments in juice extraction with two single mills, each $34'' \times 72''$ running with a peripheral speed of 8·9 feet per minute and set close to take only a thin feed.

The experiments lasted three weeks. During that period of continuous work—the only stoppages being on Sundays—the mills were never for a moment left to themselves. The crushing worked out at an average of 67·8 per cent. Mr. Fryer had throughout the experiment been making constant tests of the bagasse and he recorded it as having contained 45·34 per cent. of fibre, the fibre content of the cane for the period being 14·4 per cent. Too much care cannot possibly be bestowed upon the feeding of the mills. The Engineer may do his part by having them in the perfection of condition, but it rests with the Administration to get the perfection of work from them.

Before the days of "green" bagasse furnaces the appearance of the bagasse turned out overnight indicated the amount of care bestowed on the feeding of the mills. In these days bad work is hidden by burning up the bagasse as made. To insure good work, therefore, **it is imperative that the crushing of the mills be taken once every 24 hours. The use of storage derricks would make this a very simple and withal a very profitable operation.**

Cane Juice.

As to the quality of the cane juice, in most of the factories visited, there was much complaint.

The Boiling House Records of one Factory for the current crop showed the following figures :—

Week ended	Brix.	Sucrose.	Purity.
1913, December, 20	16·38	13·20	80·6
" " 27	16·73	13·49	80·6
1914, January, 3	16·83	13·65	81·1
" " 10	16·78	13·60	81·0
" " 17	16·80	13·63	81·1
" " 24	16·88	13·84	82·0
" " 31	17·04	13·91	81·6
" February, 7	17·00	13·87	81·5
" " 21	17·32	14·12	81·5
" " 28	17·56	14·55	82·8
Average of ten weeks	16·93	13·78	81·3
" for December	16·55	13·35	80·6
" " January	16·87	13·72	81·3
" " February	17·29	14·18	81·9

After I had left India another Bihar factory forwarded an extract from its records for the four years 1909-10 to 1912-13 and for 1913-14 down to part or the whole of the month of March 1914.

From this statement the following figures have been compiled :—

	December.		January.		February.		March.		April.		May.	
	Brix.	Sucrose.	Brix.	Sucrose.	Brix.	Sucrose.	Brix.	Sucrose.	Brix.	Sucrose.	Brix.	Sucrose.
1909-10 .	16·78	13·36	15·82	14·45	18·10	14·58	18·39	14·11	18·00	15·40	...	...
1910-11 .	15·19	12·97	16·20	13·28	17·32	14·25	16·97	14·61	17·00	14·17	...	...
1911-12 .	15·53	13·40	16·15	14·05	16·15	15·10	17·10	15·00	17·60	15·00	...	...
1912-13 .	17·17	14·67	17·35	15·39	17·75	16·05	18·17	15·57	19·15	16·22	19·40	16·20
1913-14 .	16·80	14·50	17·45	14·80	17·42	15·42	18·30	15·90	?	?	?	?
Sucrose	Average	13·78		14·40		15·08		15·04		15·33		16·20

Average sucrose for whole crop 1909-10	. . .	14·38 per cent.
" " " " 1910-11	. . .	13·96 "
" " " " 1911-12	. . .	14·51 "
" " " " 1912-13	. . .	15·01 "
to end of March (?) 1913-14	. . .	15·15 "

Canes grown without irrigation fluctuate in saccharine content with the vicissitudes of season and the above cannot be considered particularly poor juice.

From only one of the Estates visited, the one referred to on page 10, were fibre figures obtained. These were given for the current crop as 14·6 per cent.

Fibre figures at best are only an approximation more or less remote. Assuming—we can only assume—that the fibre in the cane supplied to the second factory for the crop of 1912-13 was 14·5 per cent. the sucrose content of those canes would appear to have been 12·82 per cent.

A brief résumé of the figures for 1913 for 133 Java factories is now available, and it shows that the sugar content of the canes was 12·54 per cent. against 12·35 for the previous year. The highest amount of sugar in the cane was 14·81 per cent., the lowest 9·70 per cent. The average fibre is not given, but it may not be unsafe to assume that it was less than in the Bihar cane and that the juice contained less sugar. Its average purity was 80·95 per cent. as against 81·3 per cent. in the Factory mentioned at page 12.

If the juice dealt with in these two factories is to be taken as near the average of Bihar juices that district has great possibilities.

Clarification.

In two factories outside Bihar the appliances for clarification and their arrangement were found not unsatisfactory, but in only one of these did the sulphur box appear to be thoroughly effective.

One factory only of those visited later was using the carbonatation process. Of these using sulphur only one was applying it effectively. This must not be taken to mean that its application by means of rough-and-ready furnaces and wooden boxes cannot be made thoroughly effective. Where wooden boxes were used they were found too small. The vent pipe of one was too small to keep the sulphur burning in the furnace. It was therefore useless. One of the shelves of another was at the moment of my visit lying outside the box. Its construction clearly showed the inefficiency of this box. A third was at the moment out of use

on account of a broken jet pipe. All were difficult of access for cleaning internally.

In three of the factories the clarifying arrangements consisted of a range of defecators in imitation of the French system. There is no better defecator than the French when properly arranged in a good light and carefully attended. These are insufficiently lighted where light is most required at the outlet pipes and at night in some of the ranges it must be impossible to obtain a careful separation of the clear juice from the mud or scums.

The "Eliminator" may be expected to correct this; as a matter of fact as now generally constructed it does not.

The mud subsiders in each of these three factories were of wrong dimensions. They could not be used as subsiders, consequently more liquid had to be passed through the filters than should have been and the work was imperfect. To correct this, in one case at least, a range of seven subsiders has been erected. It is needless to point to the loss of sugar which must result from the hanging up of so much juice in the factory, and heat and other losses consequent.

Evaporation.

In all the factories visited the Evaporators if kept properly clean seemed to be sufficient for their work. In some cases continuous work was said to be carried on for a couple of weeks. This is certainly not economical and the practice cannot be defended. In sugar factories generally Sunday is the most important day of the week, and the time should be fully utilized in cleaning evaporating surfaces and otherwise engaging in works of prevention.

Vacuum pans.

In most of the factories the vacuum pans were of capacity sufficient to deal effectively with the material passed on to them if helped out by crystallizers.

Crystallizers.

In only two were the crystallizers sufficient in number to insure the maximum reduction of the sucrose in the molasses. The amount of this reduction was not ascertained but a mere glance at the other installations was enough to show their deficiencies.

Quality of Sugar.

This depends to a great extent upon clarification and owing principally to the construction and arrangement of the appliances, clarification was responsible for any shortcomings in the quality of the product. In one small factory where the clarifiers were well arranged and the crystallizers adequate to the work, two sugars were being made and the quality of each was of its kind excellent.

Much has recently been written in reference to the manufacture of white sugar, and all-white-sugar at one operation, but **unless the price of the white is far enough above that of the second to compensate for a greater vacuum pan capacity, for extra centrifugals, and greater demands upon the fuel, to say nothing of a decreased extraction, he will be well advised who, having a fair market for second sugar, continues to make it.**

Extraction of Sugar.

With regard to extraction no figures extending over a number of years were obtained, but the condition of the cane yards, the poor crushing, the appliances for treatment of the juices and the shortcomings of the crystallizers taken together are sufficient to account for its being anything but high or satisfactory.

Here the manufacturing figures from Java for the crop of 1913 may again be referred to. The highest percentage of sucrose extracted by the mills from that in the cane was 95·1. This was with 11·11 per cent. of fibre in the canes and 12·7 per cent. maceration. The lowest was 84·7 per cent., with 7·91 per cent. of fibre.

This shows mill work on cane of 84·4 and 78 per cent. respectively.

The working up of the juices appears to have resulted in the following figures :—

White Sugar of . .	99·20	poln.	6·93	per cent.
Refining crystals of . .	97·18	"	1·34	"
Second boilings of . .	97·61	"	0·90	"
Molasses Sugar of . .	86·07	"	0·76	"
Black Stroop . . .			0·05	"
	Total		9·98	"

As to the number of crushes to which the cane was subjected to obtain from the mills the results given above, no information has been furnished, but it is probably safe to assume that three was a minimum, and of less frequent occurrence than four or five. No Indian mill as it stands at

present can approach this working but the addition of a third or fourth to the double mills now in use and careful feeding would make the approach a very near one, regard being had, of course, to the excess of cellulose in the Indian cane.

The result of the treatment of the Java juice shows that it must have been skilfully handled throughout—the first stage being good clarification.

With a few modifications and additions the Indian factories seen in the early part of March last need be no long way behind Java in the matter of sugar extraction.

Victoria, Vancouver, B. C.,
July 29th, 1914.

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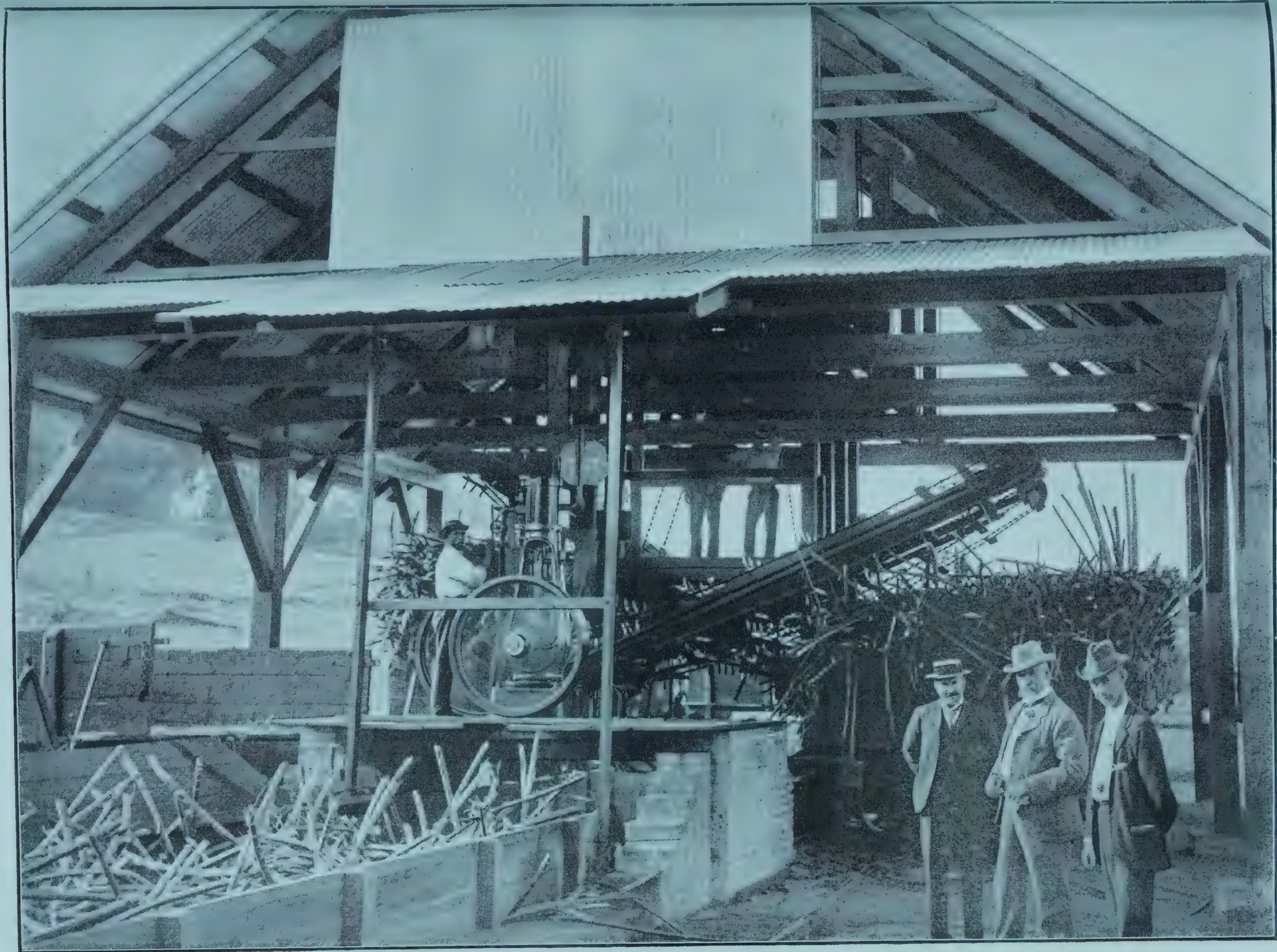

ANOTHER VIEW OF ONE PAIR OF BODLEY MALLON MACHINES IN FULL WORK.

PLATE III.

FIG. 1.—THE WICKS CANE CARRIER FEEDER AT WORK IN MEXICAN SUGAR FACTORY.

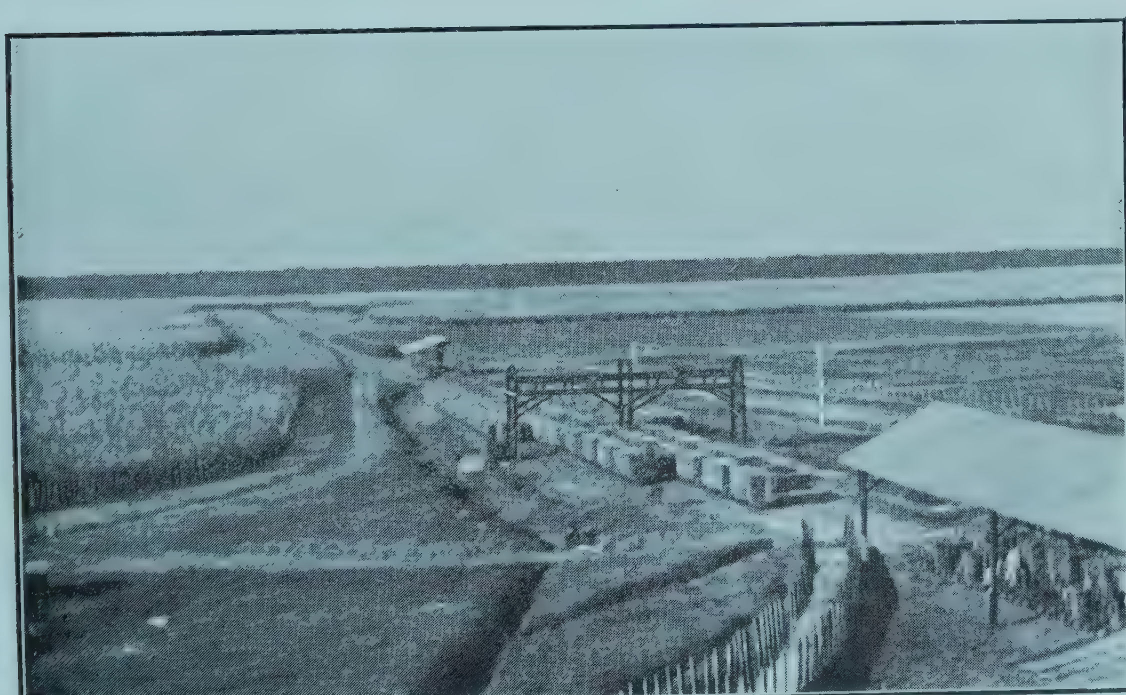

FIG. 2.—THE TRANSFER CRANE, THE EMPTY SMALL TRUCKS PASSING OUT TO THE FIELD AND THE LARGE TRUCKS BEING EMPTIED BY HAND UNDER THE CANE CARRIER SHED.

Fig. 1.—OVERHEAD CRANE AND CANE SLING IN MEXICAN SUGAR FACTORY.

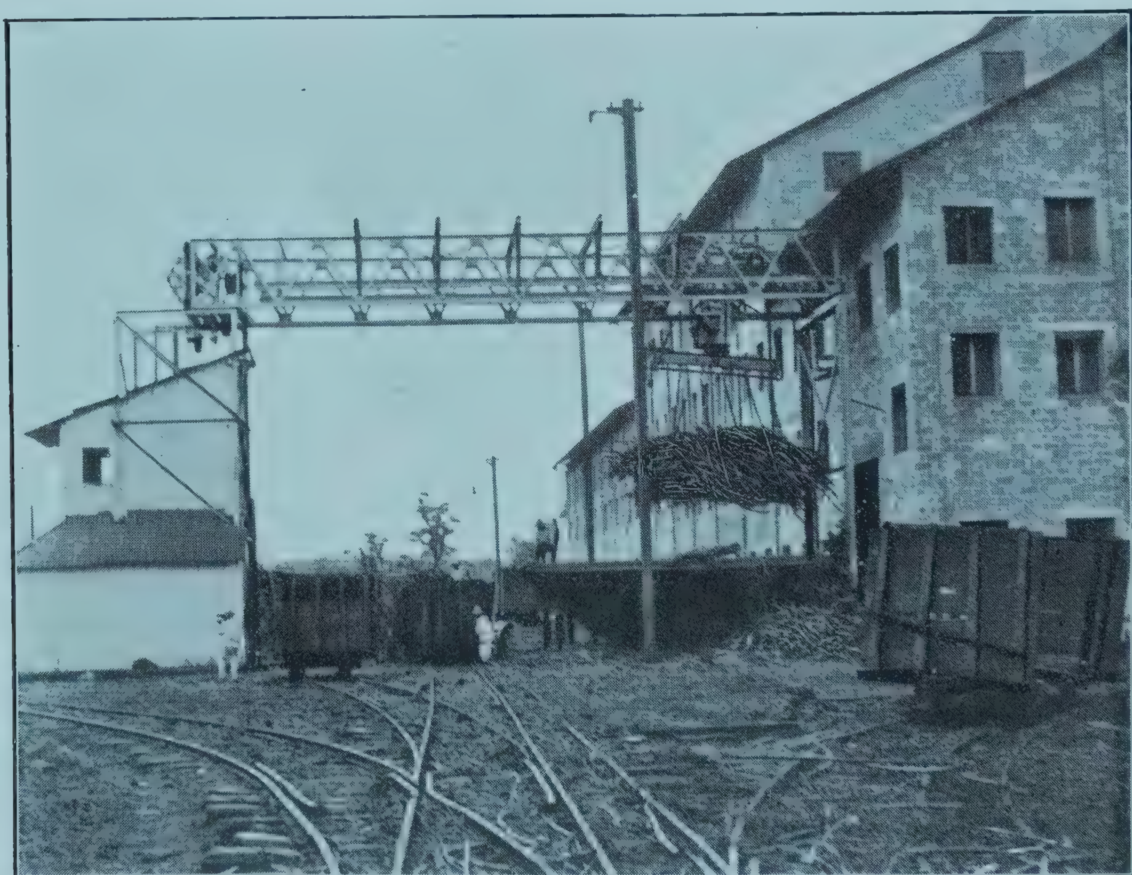

Fig. 2.—TRAVELLING CRANE AND CANE SLING IN MEXICAN SUGAR FACTORY.

PLATE V.

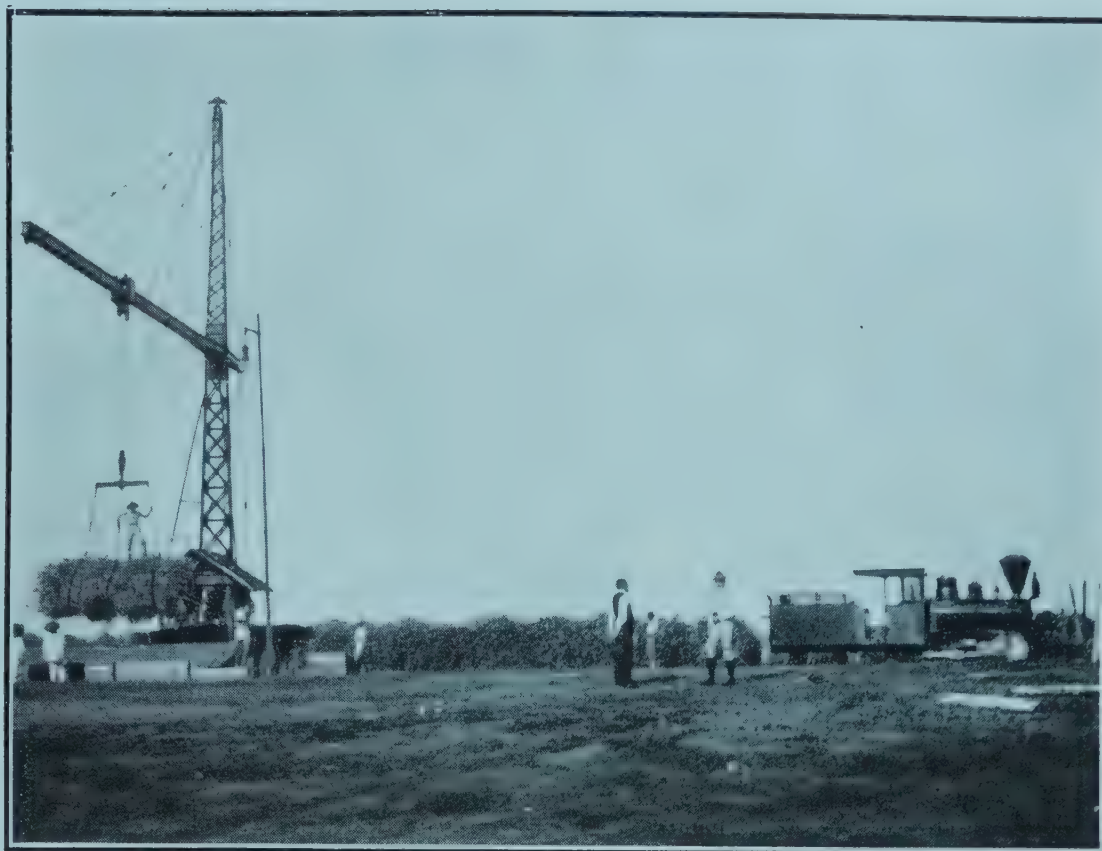

FIG. 1.—AMERICAN HOIST AND DERRICK Co.'s TRANSFER CRANE AT WORK AT MEXICAN SUGAR FACTORY.

FIG. 2.—ANOTHER VIEW OF THE DERRICK SWINGING A LOAD OF CANES ON TO CANE CARRIER PLATFORM.

ulletin No. 48 1915

Agricultural Research Institute, Pusa

irst Report on the Experiments carried out at Pusa to improve the Mulberry Silk Industry

Compiled, under the direction of the Imperial Entomologist

BY

M. N. DE,
Sericultural Assistant, Pusa

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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PREFACE.

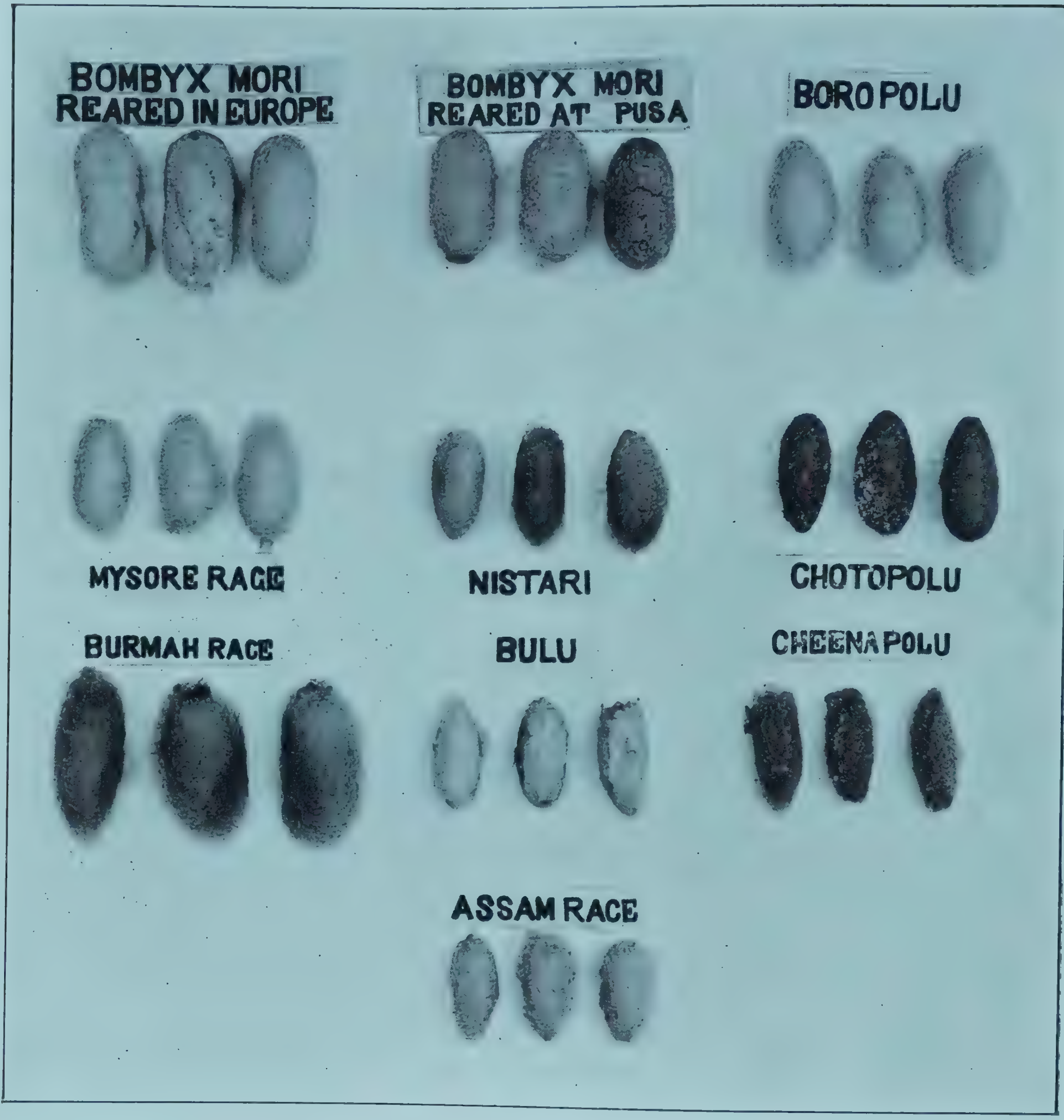
THE object of this Bulletin is to place on record some of the more important experiments which were commenced in the year 1910 and have since been carried on in the endeavour to fix a superior multivoltine race of the Mulberry Silkworm which would not degenerate and which would yield silk better both in quality and outturn than that supplied by the multivoltine races which are reared at present. This result has unfortunately not been attained as yet, but it has seemed advisable to publish the results attained hitherto and they have therefore been written up under my direction by Mr. M. N. De, under whose charge the actual work of rearing has been, since he was appointed as Sericultural Assistant at Pusa in November 1910. The practical application of the results has also been discussed from the point of view of the Silk Trade in order that they may be made as widely useful as possible. In the meantime the experiments are being continued.

We are indebted to Messrs. Anderson, Wright & Co., of Calcutta, to the Imperial Bacteriologist at Muktesar, to the Superintendent of the Shillong Farm and to Mr. Herbert T. Gill of Ramgarh (Naini Tal), for kindly helping us in preserving univoltine eggs, and to the Superintendent of Sericulture, Bengal, and the Superintendent of Sericulture, Kasimbazar Raj, Murshidabad, for supplying us with eggs of multivoltine races.

T. BAINBRIGGE FLETCHER,
Imperial Entomologist.

PUSA, BIHAR :
4th November 1914.

PLATE I.



COCOONS OF VARIOUS RACES OF THE MULBERRY SILK WORM.
(*Bombyx mori.*)

First Report on the Experiments carried out at Pusa to improve the Mulberry Silk Industry.

Introduction.

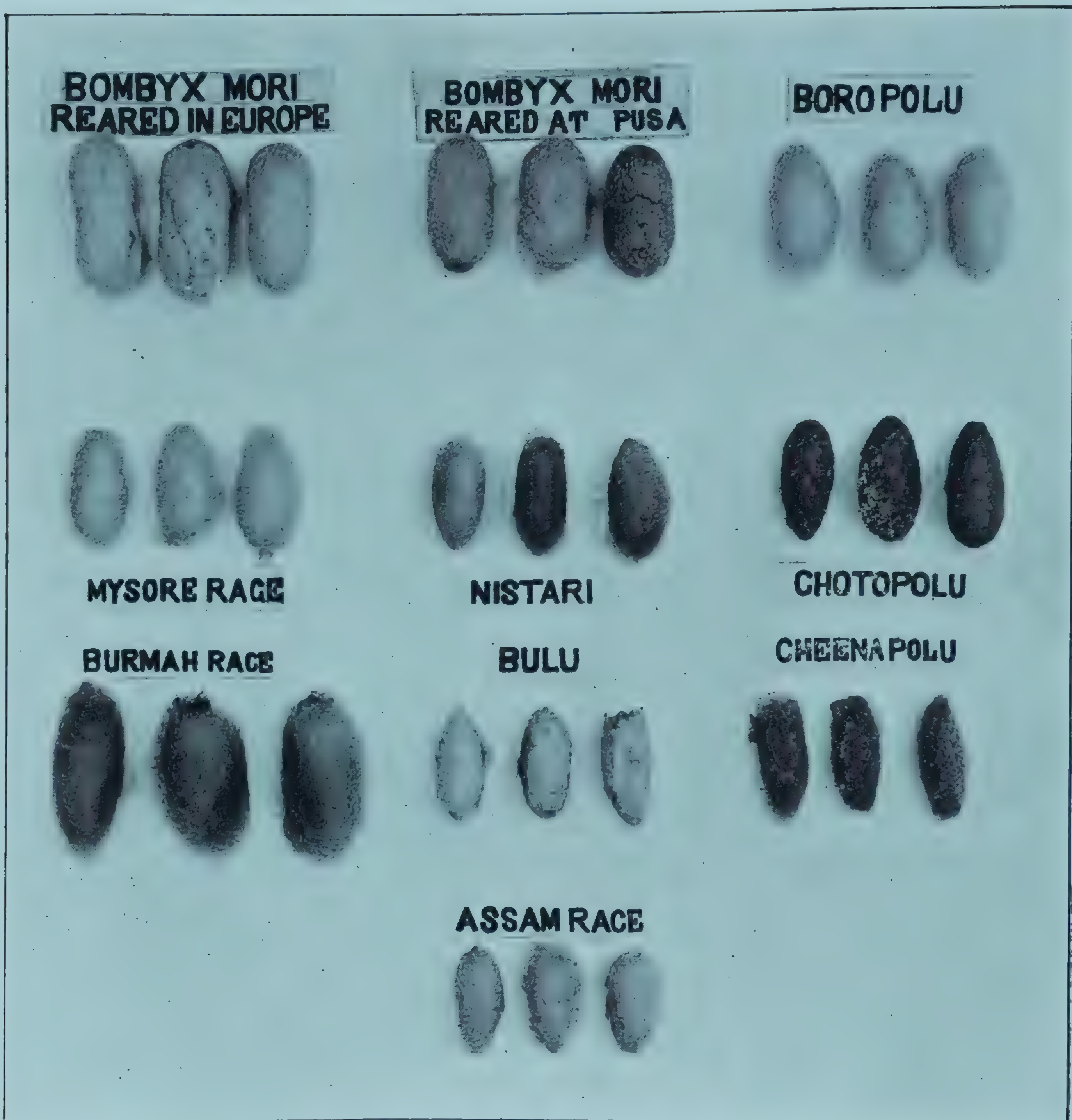
Races of Silkworms and their characteristics.

It is necessary to give a short description of the different races of silkworms reared in India and elsewhere with a view to a comparison of their characteristics and their yield of silk.

(1) *Bombyx mori* or Bilatipolu. This is the common domesticated annual silkworm cultivated in China, Japan, Italy, France, Austria, Spain, Kashmir, Turkey, Persia, Turkesthan, the Caucasus, Cyprus, etc. The cultivation of this race has recently been taken up on a small scale in Bengal, the United Provinces, the Punjab, Assam and Mysore. The eggs of this race hatch naturally once in a year after having remained in the egg-stage about ten months; it requires a certain degree of cold for the uniform and regular hatching of the eggs; the race produces yellow or white compact cocoons with or without constriction in the middle; it yields superior silk as regards both quality and outturn.

It will be shown later on that this race can be reared at any time and any number of times in a year by keeping the eggs in the cold and making them hatch at the required time. This race can be reared profitably when the temperature varies from 65° to 75° F. The principle of uniform hatching is that the eggs should be exposed after oviposition in a well-ventilated place to natural temperature for about a month and then they should be sent to a Hill Station or should be kept in a cold refrigerator at about 40°—30° F. for about four months. In cold countries for regular and simultaneous hatching the practice is to keep the cold-stored eggs in an incubator the temperature of which is gradually raised from 55° or 60° to 75° F. in 20 or 25 days, but in India they can be made to hatch (provided the temperature is not below 60° F.) uniformly and regularly within a period of about three days, ten or fifteen days after bringing them out of the cold storage if the eggs are kept in the natural temperature of a room of about 65°—80° F. like the eggs of multivoltine races.

PLATE I.



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Races of Silkworms and their characteristics.

It is necessary to give a short description of the different races of silkworms reared in India and elsewhere with a view to a comparison of their characteristics and their yield of silk.

(1) *Bombyx mori* or Bilatipolu. This is the common domesticated annual silkworm cultivated in China, Japan, Italy, France, Austria, Spain, Kashmir, Turkey, Persia, Turkesthan, the Caucasus, Cyprus, etc. The cultivation of this race has recently been taken up on a small scale in Bengal, the United Provinces, the Punjab, Assam and Mysore. The eggs of this race hatch naturally once in a year after having remained in the egg-stage about ten months; it requires a certain degree of cold for the uniform and regular hatching of the eggs; the race produces yellow or white compact cocoons with or without constriction in the middle; it yields superior silk as regards both quality and outturn.

It will be shown later on that this race can be reared at any time and any number of times in a year by keeping the eggs in the cold and making them hatch at the required time. This race can be reared profitably when the temperature varies from 65° to 75° F. The principle of uniform hatching is that the eggs should be exposed after oviposition in a well-ventilated place to natural temperature for about a month and then they should be sent to a Hill Station or should be kept in a cold refrigerator at about 40°—30° F. for about four months. In cold countries for regular and simultaneous hatching the practice is to keep the cold-stored eggs in an incubator the temperature of which is gradually raised from 55° or 60° to 75° F. in 20 or 25 days, but in India they can be made to hatch (provided the temperature is not below 60° F.) uniformly and regularly within a period of about three days, ten or fifteen days after bringing them out of the cold storage if the eggs are kept in the natural temperature of a room of about 65°—80° F. like the eggs of multivoltine races.

The time of hatching may be deferred by keeping the eggs in the cold so that a part of the eggs can be taken out for rearing at any suitable time; but the embryos will be affected if they are kept in the cold temperature for more than 12 months. If the eggs are not preserved in the cold some will hatch irregularly over a period of two or three months and not simultaneously and the worms will be weak and consequently they will spin flimsy cocoons. In this connection it should be remembered that it is essential from the rearer's point of view that all the eggs should hatch completely within a period of three or four days or it will be simply waste of time and bad economy and the rearing cannot be profitable. It should also be noted that the development of the embryo, once started after taking out of the cold storage, pursues its inevitable course and the eggs must then either hatch or die in a short time if the hibernation was of sufficient intensity and length to start the growth of the embryo, so that the eggs must be kept in the cold if they are to be preserved for a long time without hatching. But once they are taken out of the cold after the stated period it is not possible to prevent them from hatching in a short time if they are kept in a temperature of about 60°—75° F. Thus there is a complete control over the hatching of univoltine eggs by the agency of cold.

The eggs of this race are yellowish after oviposition but they change to leaden grey after three days and hibernate in that state; but two or three days prior to hatching they change to a bluish colour.

(2) Boropolu or Boropat of Assam (*Bombyx mori textor*). This is an annual race domesticated in Bengal and Assam producing a white cocoon pointed at each end. The cocoon is smaller and less compact than that of typical *Bombyx mori* as the silk is not closely wound; the yield of silk is poor when compared with that of *Bombyx mori* cocoon. The eggs do not hatch simultaneously but they continue to hatch over a period of ten or fifteen days about ten months after oviposition as they are not sent to the cold storage like the *Bombyx mori* eggs, for the illiterate cultivators of Bengal are not conversant with the principle of uniform hatching and they cannot afford to send their eggs for cold storage to distant places. These facts are unfavourable for the cultivation of the race, though it yields silk superior to some indigenous races. If arrangements could be made for distributing cold-stored eggs which would hatch uniformly in two or three days the rearing of this race and the *Bombyx mori* race could be made to assume some importance. The egg characteristics and the time of hatching, etc., of this race are exactly similar to those of the *Bombyx mori* races.

(3) Mysore race (*Bombyx mori meridionalis*). This is a multivoltine race domesticated in Mysore and Kollegal and produces soft pale sulphur-

yellow or very pale green, and slightly pointed cocoons. The eggs are yellowish after oviposition and do not change to grey like those of the annual races but they turn bluish two or three days prior to hatching just as the annuals also do. They hatch completely within a period of two or three days on the ninth (in winter on the twentieth) day after oviposition if they are kept in the natural temperature of a room of about 60°—85° F. The eggs do not require cold like the univoltine ones for uniform hatching and the hatching of the eggs can be deferred if they are kept at 40°—45° F. but the embryos will be affected if they are kept in the cold for more than thirty or thirty-five days.

This race yields silk inferior to that of the true *Bombyx mori* but it is the best of all the indigenous races. Five or six crops in a year are taken from this race. The brood characters and the egg characteristics of all the multivoltine races are similar to this race.

(4) Nistari or Madrasi Silkworm (*Bombyx mori crœsi*). This is a multivoltine race domesticated in Bengal producing pointed yellow cocoons. It is chiefly reared in March and during the Rains.

(5) Desi or Chotopolu (*Bombyx mori fortunatus*). This is a small multivoltine race cultivated in Bengal and yielding yellow or white tapering cocoons. It yields the principal cold weather crop of cocoons. The "Horupat" of Assam, which yields an inferior cocoon, probably belongs to a separate race. It spins pale sulphur-yellow cocoons.

(6) Chinapolu or Sinapolu (*Bombyx mori sinensis*) and (7) Bulu or Blue. These are multivoltine races domesticated in Bengal producing cocoons inferior to Chotopolu or Nistari. Chinapolu yields yellow and the Bulu pale greenish-white cocoons. Their cultivation has been almost entirely abandoned now.

(8) Nyapau (*Bombyx mori arracanensis*). This is a multivoltine race cultivated in Burma producing a very flimsy cocoon of white and yellow colour.

In China, Japan and Europe there are bivoltine, tri-voltine and multivoltine races of silkworms which are cultivated on a small scale. The principal foodstuffs of all the *Bombyx* races of silkworms are mulberry leaves, but in China there is a race of *Bombyx* which thrives on the leaves of *Cudrenia triloba,* Hance, and the peculiarity of this race is that it moults three times in the caterpillar stage instead of four times as is the case in almost all other *Bombyx* races. The caterpillars of this race take a greater number of days during moulting and mature on about the thirtieth day after hatching like any other *Bombyx* race.[1] All other foodplants are of indifferent value to the *Bombyx* silkworms.

[1] I reared this race in 1907 on *Cudrenia triloba* leaves at the Imperial College at Tokyo.

In the following Table the average number of empty cocoons without pupal skin contained per 10 grammes are given so that a comparison of the pure and mongrel races can be made :—

Univoltine	*Bombyx mori* cultivated in Europe	25
	Bombyx mori cultivated at Pusa	40
	Boropolu	78
Multivoltine	Mysore race	90
	Nistari	95
	Chotopolu	100
	Burma race	110
	Assam multivoltine race	116
	Bulu	130
	Chinapolu	135

Physical nature of the filaments reeled from cocoons is given in the following Table :—

Race.	Average length of one cocoon in metres.	Average denier of one filament for the length of 450 metres.	Average denier of seven filaments for the length of 450 metres.	Average tenacity of seven filaments in grammes for the length of 450 metres.	Average per cent of elasticity of seven filaments for the length of 450 metres.	REMARKS.
Mysore race	342·00	2·300	16·00	46·0	15·53	Multivoltine.
Nistari	308·66	1·800	13·50	42·6	18·40	Do.
Chotopolu	285·57	1·600	11·50	35·3	16·42	Do.
Assam race	211·40	2·400	17·25	53·8	10·77	Do.
Boropolu	279·70	2 450	17·00	47·7	12·87	Univoltine.
Bombyx mori	614·70	3·125	22·00	...	...	Do.

The Caste System and continuous supply of Mulberry leaves favour rearing of Multivoltine Races of Silkworms in India.

Bengal, Assam, Burma, Mysore, Kashmir and Jammu are the principal rearing centres in India. The annuals or one-brooded (univoltine) races, the eggs of which hatch naturally only once in a year and which yield a superior quantity and quality of silk, are cultivated in Kashmir and Jammu and the many-brooded (multivoltine) races, the eggs of which naturally hatch six or seven times in a year and which yield silk

inferior both in quality and outturn, are generally cultivated in Bengal, Assam and Mysore. In cold places the mulberry trees are denuded of their leaves in winter and so it is not possible to take more than two or three crops in a year but in a warm climate like that of India leaves are available all the year round, and these will be wasted if they are not utilized, so that it is considered economical to cultivate silkworms four or five times in a year. Besides, in India, there are numerous members of hereditary rearing castes, who solely depend upon this industry as their means of livelihood and who cannot be satisfied with only one or two crops in a year, whereas in Europe, Japan and China the industry is carried on as a subsidiary industry and the farmers are satisfied with only one or two crops in a year when agricultural operations are stopped during Spring and Autumn.

Present condition of the Silk Trade.

Sericulture in Bengal and other Provinces has been declining. There was a time when India used to export Rs. 1,55,32,290 worth of silk per year but this has now come down to Rs. 50,55,288 and expert opinions hold that the industry is doomed in a decade or two if some means are not adopted to ameliorate its condition. The majority of experts agree that the Bengal races of silkworms have degenerated and the Committee appointed by the Government of Bengal to enquire into the condition of the silk industry in 1906 was of this opinion :—" It is only to be expected that, in the course of the last 150 years during which the silk industry has been an important one in this Province, some deterioration has taken place in the worms and in the quality and quantity of silk produced by them." In spite of this degeneration the Committee recommended that only indigenous races should be reared in Bengal. It cannot be denied that the industry is decimated on account of diseases and pests and is further hampered by a want of organization for supplying disease-free eggs to the rearers.

It is apparent that, if India is to regain her old position among the silk-producing countries, a better class of worms should be introduced into the country and the only way to do this is by (1) the introduction of some suitable exotic variety, (2) cross-breeding between both indigenous and foreign races and by (3) improvement by selection of the indigenous races.

Former Attempts to improve Mulberry Silkworms in India.

A short account of the various attempts to obtain a superior cross-bred multivoltine race in India will not be out of place here.

In 1854 Mr. Bashford succeeded in producing fine cross-bred cocoons but when he distributed his stock to the local breeders it degenerated rapidly and the crop was a great failure, the worms deteriorated and proved a perfect disappointment. Subsequently Mr. Bashford had to acknowledge the failure of his endeavours as the worms reverted to annuals. Captain Hutton was all along against crossing. He pointed out : "Darwin has stated that if a plant's own pollen be brought on a brush it will invariably be pre-potent over that of a foreign species ; that is to say, Nature rejects all crossing so long as a plant's own pollen is available. Now if we apply this natural law to the silkworm it will at once show why the progeny of two different species,[1] when crossed, invariably sooner or later revert to their original state or more commonly to that of the strongest species. We cross *Bombyx fortunatus* (Chotopolu), a polyvoltine species of Bengal upon *Bombyx mori,* an imported univoltine race ; the moths produced have so to speak the blood of both species ; but when they couple there is a struggle for the mastery between the two, each striving to cast out the other and the blood of the stronger species will prove pre-potent over that of the weaker and consequently unless the latter be recrossed by its own species, it must by the law of Nature revert to an annual."

Mr. J. A. H. Louis, in his "Sericulture in Bengal," refers to a race obtained by crossing the Kashmir male moth over the Desi female but nothing has been heard of it since then.

The attempt of Mr. Cleghorn to create a hybrid race did not produce any definite result. In "Indian Museum Notes," Volume I, No. 2, page 123, we read as follows regarding his experiment : "A cross between the Desi silkworms of Bengal and the European *Bombyx mori* was reared experimentally in the hot weather of 1888, from some remarkably fine stock bred by Mr. J. Cleghorn. The results seemed promising at the first, but the insects rapidly deteriorated, the mortality being so great in the third generation that the experiment was abandoned. This confirms the generally conformed idea, which is that crosses between European and country worms (at least when reared in the way usual with Bengal silk rearers) are of no commercial value. It was considered worth while to undertake the experiment as Mr. Cleghorn's stock was distinctly finer than Bengal stock."

Miss Maude L. Cleghorn of Calcutta in her paper on "Experiments in the Inheritance of visible and invisible characters in Silkworms"

[1] The word "races" would have been a better term to have used. All these forms of *Bombyx mori* belong to one "species" in the ordinary acceptation of that term. T. B. F.

has mentioned a multivoltine hybrid race; but this, however, reverted to an annual when we tried it at Pusa.

Experiments on cross-breeding are also being done now at the Government Nursery at Berhampore and by Mrs. A. C. Ghose of Berhampore.

It appears that in Annam they have got a good result by crossing French with the Annamese races, Canton with the Annamese race, crossing the two hybrids and then crossing the product with a French strain.

Mr. Toyama of Tokyo in his "Studies on the Hybridology of Insects," Coutagne in the "Bulletin Scientifique de la France et de la Belgique," Vol. XXXVII (1903), Vernon L. Kellogg in his paper on "Inheritance in Silkworms," Signor Quajat of Padua and other foreign authors have carried on experiments from the standpoint of the colour, size and shape of the cocoons, the larval and adult characters, etc., and not from the point of view of brood characters; their experiments also were undertaken with univoltine and bivoltine races.

The material for a proper investigation of this important question is still quite insufficient. It is the experience of almost all who have made breeding experiments that there appear great aberrations in individual races. It will be seen from the experiments enumerated in this Bulletin that there are great complications in the brood characters of the mongrel silkworm races. A short account of the experiments would be of some service to those who might undertake similar experiments in future. The data at present available do not permit us to formulate any law regarding the brood characters of the mongrel races but we may perhaps be able to contribute at a subsequent date something more by way of extension and confirmation of our present experiences.

The Pusa Experiments.

The methods followed in the Pusa Experiments have been as follows :—

(*i*) We have been crossing imported univoltine races with indigenous multivoltine races, breeding their progeny, making these "self," selecting the multivoltine eggs, and discarding from each generation the univoltine eggs so as to get a "selfing" multivoltine cross-breed.

(*ii*) We have been crossing Bengal multivoltine with Mysore multivoltine race, breeding their progeny, making these "self," and breeding them again so as to produce a superior and resistant race.

(*iii*) We have been crossing between a foreign univoltine race with the indigenous univoltine race which has been acclimatized and which can stand the Indian climate so as to obtain a resistant univoltine race suitable for the climate of India.

(*iv*) With the object of ascertaining whether it is possible to rear univoltine races with bush mulberry leaves we have been importing univoltine eggs each year from foreign countries, sending them to the Hills or to some ice factory for cold storage and feeding them with the leaves of bush mulberry trees, cultivated according to the Bengal system, and comparing the results obtained with those obtained from similar lots reared on tree mulberry leaves. It should be noted that several attempts have been made to introduce foreign univoltine races in India since the time of the East India Company with indifferent results which are mainly due to the want of expert knowledge.

(*v*) We have been breeding from precocious univoltine eggs by applying artificial stimuli which will make the univoltine eggs hatch prematurely without sending them to cold storage. The practice of sending the eggs to cold storage is expensive in a country like India and this procedure can be dispensed with if some artificial means can be adopted which will ensure the uniform hatching of the eggs.

(*vi*) We have been breeding from the best specimens of the indigenous races and gradually effecting an improvement in the cocoon by careful selection. We have also been feeding the indigenous races with tree and bush mulberry leaves and comparing the results to see which kind of leaves yields better cocoons.

(*vii*) It is also thought that by adopting a course which would make the worms live under conditions analogous to natural ones some improvement in the race may be effected and with this object in view we have been trying to rear worms on trees in nets or bags.

TABLE I.

A DETAILED DESCRIPTION OF THE PUSA EXPERIMENTS.

Explanation of Abbreviations used.

P_1 = parent moth.

PLATE II.

COCOONS OBTAINED FROM THE CROSS BETWEEN UNIVOLTINE MALE AND MULTIVOLTINE FEMALE.

F_1 = first generation of P_1 offspring.
F_2 = second ,, P_1 ,,
F_3 = third ,, P_1 ,, and so on.
♀ = female moth.
♂ = male moth.
× = crossed with.
In all dates, the months are written in Roman numerals; thus, IV = April, VIII = August, etc.

The average number of P_1 male and P_1 female empty cases of cocoons in the experiment enumerated below without pupal skin per 10 grammes is equal to 40 and 90 respectively.

Multivoltine yellow Nistari ♀ was crossed over univoltine white *Bombyx mori* ♂ and the results are given as under.

F_1 Generation.

Number of Univoltine layings.	Number of Multivoltine layings.	Date of first Moulting.	Date of second Moulting.	Date of third Moulting.	Date of fourth Moulting.	Date of Mounting.	Date of Oviposition.	Number of average empty cocoons without pupal skin per 10 grammes.
Nil	All	15-I-11	24-I-11	1-II-11	13-II-11	23-II-11	11-III-11	71

The cocoons of F_1 generation were less flossy than P_1 Nistari and less compact than P_1 univoltine cocoons; there was neither a constriction in the middle like that in P_1 ♂ cocoons nor were they pointed like the P_1 ♀ cocoons The cocoons contained less silk than P_1 ♂ but more than P_1 ♀. As it was not known whether the parents of P_1 ♂ cocoons were from a pure race and whether they would breed true, much attention was not paid to the number of the coloured and white cocoons to see whether they would yield results according to the Mendelian Theory, our object being simply to get a fixed multivoltine cross-bred race superior to indigenous races. For successive generations of this race the following Table should be read. For cocoons of this race, *vide* Plate II.

TABLE I

Generation.	Date of Oviposition.	Number of Univoltine layings.	Number of Multivoltine layings.	Date of Hatching.	Date of first Moulting.
F_2	11-III-11 .	All	*Nil*	27-X-11 .	30-X-11 .
F_3	17-XII-11 .	100	5	13-I-12 .	19-I-12 .
F_3	Do. .	100	5	12-III-12 .	..
F_4	14-III-12 .	4	44	1-IV-12 .	5-IV-12 .
F_5	8-V-12 .	5	11	17-V-12 .	20-V-12 .
F_6	16-VI-12 .	12	10	21-VI-12 .	28-VI-12 .
F_7	23-VII-12 .	2	7	31-VII-12 .	3-VIII-12 .
F_8	29-VIII-12	2	20	6-IX-12 .	11-IX-12 .
F_8	..	..	..	..	..
F_9	7-X-12 .	4	50	16-X-12 .	20-X-12 .
F_{10}	18-XI-12 .	9	75	11-XII-12 .	23-XII-12 .
F_{11}	18-II-13 .	2	55	9-III-13 .	16-III-13 .
F_{12}	20-IV-13 .	*Nil*	All	29-IV-13 .	3-V-13 .
F_{13}	3-VI-13 .	*Nil*	All	11-VI-13 .	14-VI-13 .
F_{14}	9-VII-13 .	4	300	17-VII-13	20-VII-13 .
F_{15}	12-VIII-13.	4	20	20-VIII-13	22-VIII-13
F_{16}	19-IX-13 .	5	100	28-IX-13 .	1-X-13 .
F_{17}	30-X-13 .	3	75	12-XI-13 .	18-XI-13 .
F_{18}	22-I-14 .	5	100	18-II-14 .	23-II-14 .
F_{19}	19-IV-14 .	2	90	28-IV-14 .	2-V-14 .
F_{20}	2-VI-14 .	2	95	11-VI-14 .	14-VI-14 .
Mysore female $\times F_{20}$ male } F_1	11-VII-14 .	*Nil*	All	20-VII-14 .	23-VII-14 .
F_2	16-VIII-14.	..	..	..	..

—*contd.*

Date of second Moulting.	Date of third Moulting.	Date of fourth Moulting.	Date of Mounting.	Number of empty cocoons without pupal skin per 10 grammes.	REMARKS.
3-XI-11 .	8-XI-11 .	13-XI-11 .	21-XI-11 .	70	The eggs were sent to cold storage in May and brought back in October.
26-I-12 .	3-II-12 .	13-II-12 .	24-II-12 .	110	Here and in successive generations the results of rearing from the multivoltine layings are given.
..	..	..	..	..	A few of F_3 univoltine eggs began to hatch very irregularly as they were exposed to artificial stimuli to be described later on.
10-IV-12 .	15-IV-12 .	20-IV-12 .	27-IV-12 .	90	
24-V-12 .	28-V-12 .	1-VI-12 .	6-VI-12 .	95	
30-VI-12 .	4-VII-12 .	9-VII-12 .	14-VII-12 .	86	
5-VIII-12 .	9-VIII-12	14-VIII-12.	19-VIII-12.	90	
16-IX-12 .	22-IX-12 .	29-IX-12 .	6-X-12 .	84	Eggs of F_8 generation were reared in two lots.
..	..	..	..	77	Some multivoltine layings of F_8 sent to Berhampore Central Nursery for changes of seed.
23-X-12 .	27-X-12 .	4-XI-12 .	16-XI-12 .	75	These eggs were from the Berhampore lot.
31-XII-12 .	8-I-13 .	28-I-13 .	8-II-13 .	110	The seed cocoons were put into hot incubator at about 75°F. for the speedy emergence of the moths.
22-III-13 .	27-IV-13 .	3-V-13 .	9-V-13 .	130	The cocoons were very small in this generation.
10-V-13 .	14-V-13 .	19-V-13 .	25-V-13 .	100	
16-VI-13 .	18-VI-13 .	21-VI-13 .	30-VI-13	70	
23-VII-13 .	27-VII-13 .	31-VII-13 .	4-VIII-13 .	90	Very few eggs of some layings were partly multivoltine and partly univoltine.
25-VIII-13	28-VIII-13.	31-VIII-13.	9-IX-13 .	90	Some layings were partly univoltine and partly multivoltine.
4-X-13 .	7-X-13 .	11-X-13 .	19-X-13 .	100	
25-XI-13 .	3-XII-13 .	11-XII-13 .	31-XII-13 .	135	
28-II-14 .	10-III-14 .	22-III-14 .	8-IV-14 .	100	
7-V-14 .	11-V-14 .	15-V-14 .	23-V-14 .	90	
16-VI-14 .	19-VI-14 .	24-VI-14 .	30-VI-14 .	80	The male of this generation was crossed with female of Mysore race and this race will be named $\left.\begin{array}{l}\text{Mysore female}\\ \times F_{20}\text{ male}\end{array}\right\} F_1$
26-VII-14 .	29-VII-14 .	31-VII-14 .	9-VIII-14 .	50	
..	..	..	..	..	The race is being continued

We do not think it advisable to discard the univoltine layings and to distribute the multivoltine layings to the cultivators, though in some generations they have given better crops than the indigenous races, as we have to militate against the probable existence of strain idiosyncrasy, for it is quite possible that the progeny of the multivoltine layings may turn to an annual race; another difficulty which we have met with is the natural tendency of degeneration in the worms and consequently in the cocoons after some generations in the worms. The vigour of the worms may be kept up by the infusion of new blood, *i.e.*, by repeated crossing after some generations, but there is possibility of the race reverting to an annual one. We have been continuing the experiment to see whether our efforts to fix a multivoltine cross-bred race, which would not degenerate, would be successful.

The univoltine layings from some of the generations were selected and sent to cold storage for uniform hatching and reared in due course. All the eggs of successive generations were found to be univoltine. The results of rearing the univoltine layings of some generations are enumerated below. The cocoons produced from the univoltine layings were far superior to those obtained from the multivoltine layings in the same generations. The shape and size of these cocoons were different from the multivoltine ones. In some there was a little constriction in the middle but others were pointed.

In some generations the worms were reared separately in two or three lots to select distantly connected moths for crossing in successive generations to infuse new blood in the progeny.

Generation.	Date of Oviposition.	Date of Hatching.	Date of first Moulting.	Date of second Moulting.	Date of third Moulting.	Date of fourth Moulting.
F_2 . . .	11-III-11 .	27-X-11 .	30-X-11 .	3-XI-11 .	8-XI-11 .	13-XI-11 .
F_3 . . . & F_6 . . .	5-XII-11 . 16-VI-12 .	6-III-13 .	13-III-13 .	19-III-13 .	1-IV-13 .	6-IV-13 .
F_4 . . . & F_7 . . .	17-IV-13 .	6-XI-13 .	11-XI-13 .	19-XI-13 .	27-XI-13 .	5-XII-13 .

Date of Mounting.	Number of empty cocoons without pupal skin per 10 grammes.	Date of sending eggs for cold storage.	Date of bringing back the eggs from cold storage.	REMARKS.
21-XI-11 . .	75	2-V-11 .	21-X-11 .	These eggs are from the univoltine layings.
9-IV-13 . .	70	12-VIII-12	24-II-13 .	The eggs were mixed up and reared together.
25-XII-13 . .	60	20-IV-13 .	26-X-13 .	

TABLE II.

Results of crosses between univoltine male and multivoltine female and *vice versâ* are enumerated in this Table.

Race.	Generation.	Date of Oviposition.	Number of Univoltine layings.	Number of Multivoltine layings.	Date of Hatching.	Cocoons if superior to Multivoltine P_1 race.	Remarks.
Multivoltine Burma female × Univoltine Italian-Japanese male	F_1 .	30-IV-11 .	*Nil*	All	11-V-11 .	Superior.	
Do.	F_2 .	7-VI-11 .	All	*Nil*	11-25-I-12 .	Do. .	The eggs were not sent to cold storage but kept suspended in a room in an earthen vessel as is the practice in Bengal with Boropolu eggs.
Univoltine female × Multivoltine Burma male.	F_1 .	1-V-11 .	All	*Nil*	October 1911.	Superior.	
Univoltine female × Nistari male	F_1 .	14-IV-11 .	All	*Nil*	February 1912.	Do.	
Do.	F_2 .	25-III-12 .	..	6	7-IV-12 .	Do.	
Do.	F_3 .	17-V-12 .	..	10	27-V-12 .	..	All the worms were killed by parasitic flies.
Boropolu female × Chotopolu male.	F_1 .	15-IV-11 .	All	*Nil*	17-I-12 .	..	The cocoons were very small and therefore the race was given up.
Boropolu female × Nistari male	F_1 .	8-IV-11 .	All	*Nil*	17-I-12 .	Superior.	
Do.	F_2 .	27-III-12 .	9	32	7-IV-12 .	Do.	
Do.	F_3 .	10-V-12 .	9	3	23-V-12 .	Do.	
Do.	F_3 .	10-V-12 .	..	..	12-X-12 .	Very poor cocoons.	
Do.	F_4 .	4-XII-12 .	47	*Nil*	27-II-13 .	Do. .	4 or 5% from all the layings began to hatch from 27-II-13. The race was given up.
Boropolu female × Mysore male	F_1 .	8-IV-11 .	All	*Nil*	29-I-12 .	Superior.	
Do.	F_2 .	23-III-12 .	3	8	8-IV-12 .	Do.	
Do.	F_3 .	15-V-12 .	8	11	23-V-12 .	Cocoons were poor.	The race was given up.
Boropolu female × Nistari male	F_1 .	18-IV-11 .	All	*Nil*	1-II-12 .	Superior.	
Do.	F_2 .	25-III-12 .	*Nil*	5	7-IV-12 .	Do.	
Do.	F_3 .	14-V-12 .	20	15	23-V-12 .	Do. .	The race was discontinued.
French male × Chotopolu female	F_1 .	6-II-12 .	*Nil*	All	26-II-12 .	Do.	
Do.	F_2 .	12-IV-12 .	All	*Nil*	12-X-12 .	Do.	
Do.	F_3 .	6-XII-12 .	All	*Nil*	..	..	The race was discontinued.
Chotopolu male × French female	F_1 .	6-II-12 .	All	*Nil*	12-X-12 .	Superior.	

TABLE II—*contd.*

Race.	Generation.	Date of Oviposition.	Number of Univoltine layings.	Number of Multivoltine layings.	Date of Hatching.	Cocoons if superior to Multivoltine P_1 race.	REMARKS.
Chotopolu male × French female	F_2 .	25-XI-12 .	All	*Nil*	..	..	The race was discontinued.
French female × Nistari male.	F_1 .	27-III-11 .	All	*Nil*	15-I-12 .	Superior.	
Do.	F_2 .	28-III-12 .	*Nil*	6	7-IV-12 .	Do.	
Do.	F_3 .	12-V-12 .	All	*Nil*	..	..	The race was discontinued.
Japanese male × Nistari-Mysore female.	F_1 .	10-IV-12 .	*Nil*	All	19-IV-12 .	Superior.	
Do.	F_2 .	19-V-12 .	All	*Nil*	..	..	The race was given up.
Nistari female × Italian-Japanese male.	F_1 .	19-IV-12 .	*Nil*	All	28-IV-12 .	Superior.	
Do.	F_2 .	22-V-12 .	All	*Nil*	..	..	The race was given up.
Chotopolu female × Italian-Japanese male.	F_1 .	18-V-12 .	*Nil*	All	28-V-12 .	Superior.	
Do.	F_2 .	20-V-12 .	All	*Nil*	..	..	The race was given up.
Do.	F_1 .	27-IV-14 .	*Nil*	All	6-V-14 .	Superior.	
Do.	F_2 .	9-VI-14 .	5	*Nil*	..	..	The race is being continued.
Chotopolu female × Boropolu-French male.	F_1 .	8-XII-12 .	*Nil*	All	8-I-13 .	Superior .	Results of multivoltine layings are given here and in the successive generations.
Do.	F_2 .	21-III-13 .	157	133	31-III-13 .	Superior .	There was great mortality in the caterpillar stage.
Do.	F_3 .	9-V-13 .	8	11	19-V-13 .	Do.	
Do.	F_4 .	20-VI-13 .	3½	3½	29-VI-13 .	Do.	
Do.	F_5 .	30-VII-13	3	3	7-VIII-13 .	poor cocoons.	
Do.	F_6 .	6-IX-13 .	..	5	15-IX-13 .	very poor cocoons.	
Do.	F_7 .	18-X-13 .	..	..	..	..	The race was abandoned. Four layings were unfertilized in this generation.
French Boropolu female × Nistari male.	F_1 .	9-XII-12 .	5	*Nil*	..	..	Twenty eggs hatched from one laying on 27-II-13. They were reared but all of them died.
Mysore-Nistari female × French male.	F_1 .	17-V-14 .	*Nil*	42	26-V-14 .	Superior.	
Do.	F_2 .	27-VI-14 .	15	*Nil*	..	..	The race is being continued.
Italian-Japanese female × Nistari male.	F_1 .	29-IV-14 .	12	*Nil*	..	..	Do.
Mysore-Nistari female × Boropolu male.	F_1 .	6-IV-14 .	*Nil*	All	17-IV-14 .	Superior.	
Do.	F_2 .	22-V-14 .	All	*Nil*	..	..	The race is being continued.
Italian-Japanese female × Chotopolu male.	F_1 .	27-IV-14 .	4	*Nil*	..	..	The race is being continued.

From the above experiments we can safely conclude that the brood character is maternal in the first cross generation but that there are complications in the later generations. It will be noticed that eggs have become univoltine in the successive generations though the parent layings were multivoltine. The results as regards the brood characters in these silkworms do not seem to conform to Mendel's Law. The laws of heredity in silkworms, as far as the brood characters are concerned, are so complicated that it may almost be said that, so far as we can see at present, no law exists.

Thus it is possible to get superior cocoons if the eggs are obtained from a cross between the female of a multivoltine race and male of an annual race; the eggs in the first generation will hatch ten or twelve days after oviposition like the multivoltine ones; but in the next generation the eggs will turn to univoltine. If the male moth of this mongrel race is made to pair with the female of a multivoltine race, the eggs in the first generation will be multivoltine and the cocoons, produced by them, will be superior to the best multivoltine races. If the male of this generation is made to pair with a multivoltine female, the eggs in the first generation of this cross will turn to multivoltine and the cocoons will be superior to multivoltine ones. So in each generation if a male univoltine or a male of a superior mongrel race of any generation is made to pair with a female of a multivoltine race the crop will be far superior to indigenous races. Thus superior cocoons can be obtained in all the *Bunds* (seasons) if the indigenous multivoltine races are supplanted by the above-mentioned mongrel races. But the question is whether it will be possible to supply all the cultivators with the eggs of the above races in each *Bund*. It should be noted that all the eggs of the above female mongrel races will turn to univoltine in the second generation and they will be wasted if they are not sent to cold storage for uniform hatching. It should be further noticed that at present the cultivators procure seed-cocoons and not eggs from distant localities for rearing purposes; but if the above procedure were adopted, eggs would have to be supplied to all the cultivators, and it would be very unlikely that they would follow special directions for rearing them.

At present the cultivators of Bengal alone require about Rs. 1,50,000 worth of eggs annually; but all the Government and private nurseries cannot supply more than Rs. 10,000 worth of eggs. Taking for granted that all the existing nurseries were to begin to produce eggs as directed above, the supply would still be quite inadequate.

TABLE III.

Results of the crosses between different varieties of univoltine races.

Race.	Generation.	Date of Oviposition.	Number of Univoltine layings.	Number of Multivoltine layings.	Date of Hatching.	REMARKS.
French male × Italian-Japanese female	F_1	28-IV-11	All	*Nil*	20-X-11.	
Do. . .	F_2	10-XII-11	All	*Nil*	14-X-12.	
Boropolu male × French female	F_1	13-IV-11	All	*Nil*	1-II-12	
Do. . .	F_2	31-III-14	1	15	9-IV-12	The Multivoltine layings in this generation are curious.
Do. . .	F_3	17-V-12	All	*Nil*	11-XII-12	
French female × Italian male	F_1	15-III-11	All	*Nil*	15-X-11.	
Boropolu female × French male	F_1	13-IV-11	All	*Nil*	1-II-12.	
Do. . .	F_2	27-III-12	6	3	8-IV-12	The Multivoltine layings in this generation appear to be curious.
Do. . .	F_2	27-III-12	168	*Nil*	20-X-12.	

Mr. Goodman pointed out at the Special Meeting of the Bengal Silk Committee held on 31st March 1913 that from seed supplied in 1910 a cross between Italian and Japanese moths became multivoltine in the 5th generation. According to M. Lafont, Professor of Sericultural Research, Berhampore, Bengal, univoltine eggs are turned to multivoltine in the climate of Madagascar. In Japan some univoltine eggs were turned to trivoltine when kept in a room at a certain degree of temperature. The untimely hatching of the eggs in the above Table may be due to climate and temperature.

We have seen by practical tests that crosses between a univoltine race and Boropolu are more resistant to diseases and can be reared in those places where pure imported races do not thrive well. As Boropolu has been acclimatized in India for a long time it can stand the Indian climate better and therefore the crosses between this and the univoltine races give satisfactory results.

PLATE III.

FIGURE 1.—COCOONS OBTAINED FROM THE CROSSES BETWEEN FOREIGN AND INDIGENOUS UNIVOLTINE RACES.

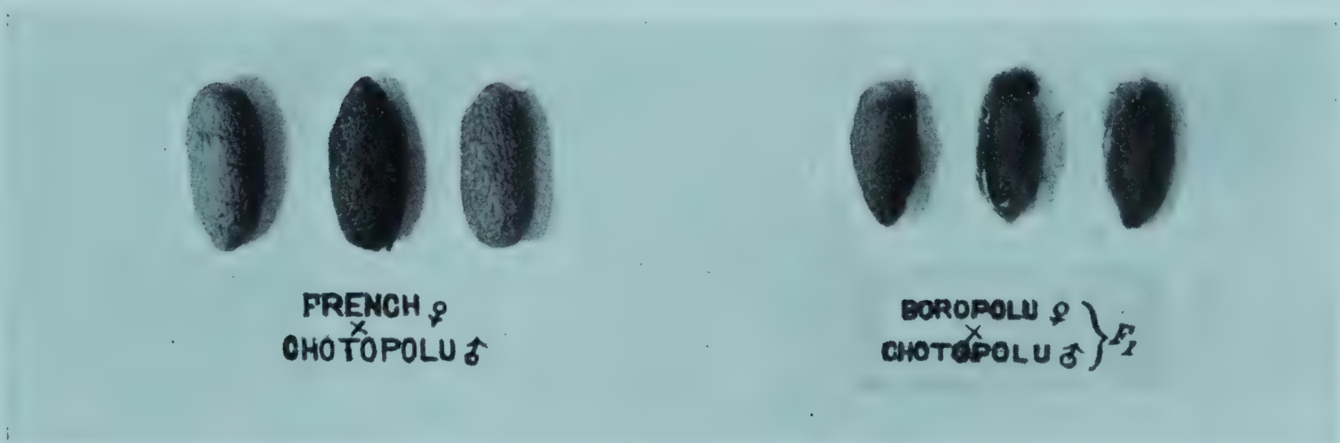

FIGURE 2.—COCOONS OBTAINED FROM THE CROSSES BETWEEN UNIVOLTINE FEMALE AND MULTIVOLTINE MALE.

TABLE IV.

In this Table the description of the crosses between multivoltine races are enumerated.

Race.	Gener-ation.	Number of Univoltine layings.	Number of Multivoltine layings.	Date of Oviposition.	Date of Hatching.	Date of Mounting.	Number of empty cocoons without pupal skin per 10 grammes.	REMARKS.
Mysore female × Nistari male.	F_1	*Nil*	All	6-I-11 .	30-I-11 .	6-III-11 .	78	All the cocoons were yellow in F_1 generation. Eggs from yellow cocoons were kept in all the generations.
Do. .	F_2	*Nil*	All	22-III-11 .	6-IV-11 .	3-V-11 .	85	Some of the cocoons were yellow, some were white and some were greenish white.
Do. .	F_3	*Nil*	All	15-V-11 .	22-V-11 .	16-VI-11 .	80	
Do. .	F_4	3	108	28-VI-11 .	6-VII-11 .	29-VII-11	79	
Do.	F_5	4	98	6-VIII-11 .	14-VIII-11	5-IX-11 .	70	
Do. .	F_6	4	100	15-IX-11 .	24-IX-11 .	15-X-11 .	74	
Do. .	F_7	5	106	26-X-11 .	8-XI-11 .	4-I-12 .	87	
Do. .	F_8	6	93	..	25-I-12 .	3-III-12 .	95	All the F_4, F_5, F_6, F_7 and F_8, pigmented leaden grey eggs began to hatch from 10-18 IV-12.
Do .	F_9	*Nil*	All	17-III-12	27-III-12 .	26-IV-12 .	75	
Do. .	F_{10}	2	58	6-V-12 .	14-V-12 .	6-VI-12 .	93	
Do. .	F_{11}	2	100	16-VI-12	23-VI-12 .	12-VII-12	97	The pigmented univoltine eggs of this generation hatched on 23-II-13.
Do. .	F_{12}	9	151	23-VII-12	31-VII-12	17-VIII-12	83	
Do. .	F_{13}	2	109	26-VIII-12	4-IX-12 .	24-IX-12 .	80	
Do. .	F_{14}	1	50	2-X-12. .	12-X-12	10-XI-12 .	79	
Do. .	F_{15}	19	10	27-XI-12 .	26-XII-12	16-II-13 .	90	F_{15} pigmented eggs hatched on 17-II-13 and matured on 26-III-13
Do. .	F_{16}	*Nil*	10	14-III-13 .	29-III-13 .	..	..	All died.
Do. .	F_{16}	*Nil*	All	6-IV-13 .	14-IV-13 .	11-V-13 .	83	These eggs are from the second generation of F_{15} pigmented eggs.

TABLE IV—*contd.*

Race.	Generation.	Number of Univoltine layings.	Number of Multivoltine layings.	Date of Oviposition.	Date of Hatching.	Date of Mounting.	Number of empty cocoons without pupal skin per 10 grammes.	REMARKS.
Mysore female × Nistari male.	F_{17}	*Nil*	All	20-V-13 .	28-V-13 .	18-VI-13 .	95	
Do. .	F_{18}	*Nil*	All	26-VI-13 .	5-VII-13 .	25-VII-13	84	
Do. .	F_{19}	19%	81%	2-VIII-13 .	11-VIII-13	30-VIII-13	83	
Do. .	F_{20}	21%	79%	8-IX-13 .	16-IX-13 .	7-X-13 .	80	
Do. .	F_{21}	20%	80%	25-X-13 .	3-XI-13 .	23-XI-13 .	82	
Do. .	F_{22}	25%	75%	15-XII-13	13-II-14 .	25-III-14 .	83	The multivoltine eggs were destroyed and the pigmented eggs were kept for rearing.
Do. .	F_{23}	*Nil*	All	4-IV-14 .	15-IV-14 .	8-V-14 .	93	
Do. .	F_{24}	*Nil*	All	19-V-14 .	27-V-14	16-VI-14 .	116	
Do. .	F_{25}	*Nil*	All	26-VI-14 .	4-VII-14 .	23-VII-14	86	
Do. .	F_{26}	*Nil*	All	31-VII-14	9-VIII-14 .	27-VIII-14	96	
Do. .	F_{27}	*Nil*	All	5-IX-14 .	13-IX-14 .	30-X-14 .	..	The race is being continued.
Mysore female × Nistari ChotopoluF$_3$male	F_1	*Nil*	All	22-VIII-14	30-VIII-14	19-IX-14 .	72	
Do. .	F_2	5	27	..	..	..	..	The race is being continued.

The pigmented leaden grey eggs in the fourth and successive generations of this race appear to be curious for it is expected that the eggs oviposited by a cross between multivoltine races will be multivoltine in all the generations. These eggs showed the characteristics of univoltine eggs but they did not require cold like univoltine eggs for their uniform hatching, for they began to hatch naturally about two to four months after oviposition. This is a case of reversion. The reciprocal cross (Nistari ♀ × Mysore ♂) exhibited the same characteristics, as far as the pigmented eggs are concerned, up to eleventh generation, when the race was abandoned.

In 1912 we received some seed cocoons of Chinapolu and Nistari races from Mr. M. C. Roy of Kasimbazar and the Superintendent of Sericulture, Bengal; it was found, when the moths from these two lots oviposited, that some percentage of the eggs were pigmented like the

above. Captain Hutton has described some "vivaceous eggs from some of his Chinapolu layings" (*vide* "On the Reversion and Restoration of the Silkworm," Part II, page 315). Table XI should be read along with it. We do not recommend the distribution of seed cocoons, the progeny of which will not hatch like the eggs of the multivoltine races as there will be confusion and bad economy.

TABLE V.

The following experiments were undertaken to see for how long the multivoltine eggs can be prevented from hatching if they are preserved in the cold and whether good cocoons can be obtained from cold-stored eggs.

When eggs are ready to hatch leaves are not always available for rearing the worms; so it would be a great convenience if the hatching of the multivoltine eggs could be retarded for some time, so that suitable leaves would be available at the time of hatching, since otherwise the eggs would have to be destroyed for want of leaves. Some maintain that the indigenous worms have become degenerated by being forced into unduly rapid reproduction (*vide* Geogheghan's "Silk in India," page 34, paragraph 34). The following experiments were carried out to show the truth or otherwise of such a statement.

Race.	Date of Oviposition.	Date of sending eggs for cold storage.	Temperature of the incubator or of the room.	Date of bringing back from the cold incubator.	Date of Hatching.	Date of Mounting.	Remarks.
Mysore female × Nistari male. F_7	16-X-11	20-X-11	62°-64° F.	25-X-11.	29-X-11	1-XII-11	
Do.	16-X-11	20-X-11	62°-64° F.	27-X-11.	30-X-11	3-XII-11	
Do.	16-X-11	20-X-11	62°-64° F.	30-X-11	31-X-11	8-XII-11	
Do.	16-X-11	20-X-11	62°-64° F.	31-X-11	1-XI-11	8-XII-11	
Do.	16-X-11	20-X-11	62°-64° F.	1-XI-11	1-XI-11	8-XII-11	
Do.	16-X-11	20-X-11	62°-64° F.	3-XI-11	2-XI-11 3-XI-11	12-XII-11	The eggs hatched in the incubator on 2-XI-11.
Do.	16-X-11	Kept in an ordinary room.	75°-85° F.	..	26-X-11	21-XI-11	Eggs kept in the room temperature.
Chinapolu	19-X-11	20-X-11	62°-64° F.	7-XI-11	7-XI-11	17-XII-11	
Do.	19-X-11	20-X-11	62°-64° F.	8-XI-11	8-XI-11	22-XII-11	Half of the eggs hatched in the incubator.
Do.	17-X-11	..	75°-85° F.	..	27-X-11	26-XI-11	Eggs kept in the room temperature.

Race.	Date of Mounting.	Date of sending the cocoons in the cold incubator.	Temperature of the incubator or of the room.	Date of bringing back from the incubator.	Date of emergence of the moths and Oviposition.	REMARKS.
Mysore female × Nistari male } F_6	15-X-11 .	20-X-11 .	..	27-X-11 .	30-X-11	The eggs were uniformly laid.
Do. .	15-X-11 .	20-X-11 .	..	2-XI-11 .	2-XI-11	
Do. .	15-X-11 .	..	75°-85° F.	..	26-X-11	

Thus it is possible to retard the hatching of the multivoltine eggs if cocoons and eggs are kept in the cold incubator for about twenty-five days without any injury to the embryos. Practically there is no difference between the cocoons produced from the cold-stored eggs and normal eggs though in some cases the cocoons produced from the former were a little smaller.

TABLE VI.

From the following Table it will be seen that the yield of silk is always better both in the case of univoltine (whether imported or acclimatized in India) and multivoltine races if the worms are fed with tree mulberry leaves. It is for this reason that we recommend the extension of tree mulberry plantation everywhere. It is no doubt difficult to procure tender leaves suitable for the worms of the first two stages from tree mulberry in all seasons except Spring; but this disadvantage can be obviated if a small additional plot of bush plantation is kept for the young worms.

Race.	Foodstuffs.	Date of Hatching.	Date of Mounting.	Weight of 20 empty cocoons without pupal skin in grains.	REMARKS.
Nistari . .	Bush mulberry leaves.	3-III-12 .	9-IV-12 .	23·6	
Do. . .	Cultivated tree mulberry leaves.	3-III-12 .	9-IV-12 .	26·5	
Do. .	Wild tree mulberry leaves.	4-III-12 .	10-IV-12 .	25·3	
Italian-Japanese .	Do. . .	13-III-12 .	14-IV-12 .	42·0	
Do. . .	Cultivated tree mulberry leaves.	13-III-12 .	13-IV-12 .	53·7	
Do. . .	Leaves from bush .	13-III-12 .	14-IV-12 .	37·7	
Boropolu . .	Cultivated tree mulberry leaves.	1-II-12 .	14-III-12 .	29·6	Suitable leaves were not available and hence the growth of the worms was not satisfactory.
Do. . .	Bush mulberry leaves	1-II-12 .	17-III-12 .	37·2	
Nistari × Univoltine	Wild tree mulberry leaves.	27-X-11 .	29-XI-11 .	45·2	
Do. . .	Leaves from bush .	28-X-11 .	29-XI-11 .	40·6	

TABLE VI—*contd.*

Race.	Foodstuffs.	Date of Hatching.	Date of Mounting.	Weight of 100 raw cocoons in grains.	Weight of 100 pierced cocoons in grains.	REMARKS.
Italian × Japanese .	Cultivated tree mulberry leaves.	31-III-14 .	26-IV-14 .	156·8	28·0	
Do. . .	Bush mulberry leaves.	30-III-14 .	27-IV-14 .	134·4	25·2	
Mysore × Nistari .	Bush mulberry leaves.	4-VII-14 .	23-VII-14	130·0	10·6	
Do. . .	Cultivated tree mulberry leaves .	4-VII-14 .	23-VII-14	100·0	11·7	
Mysore . . .	Bush mulberry leaves.	23-VII-14	15-VIII-14	100·0	..	
Do. . .	Cultivated tree mulberry leaves.	24-VII-14	16-VIII-14	90·0	..	

TABLE VII.

The results from the following Table show that it is possible to get satisfactory crops both from newly-imported and acclimatized univoltine eggs.

Race.	Brood.	Date of Hatching.	Date of Mounting.	Weight of 100 pierced cocoons in grains.	REMARKS.
Italian × Japanese .	First .	19-III-11 .	23-IV-11	13	The eggs were received from Messrs. Anderson, Wright and Co. of Calcutta.
Do. . .	Second	5-XI-11 .	19-XII-11	14	
Do. . .	Third .	12-X-12 .	11-XI-12 .	25	
Do. . .	Fourth .	12-III-14 .	10-IV-14 .	33	
Do. . .	First .	6-III-13 .	9-IV-13 .	17	Do.
Do. . .	Second .	14-III-14 .	12-IV-14 .	25	

Some maintain that univoltine eggs should be imported every year. This Table shows that good crops can also be obtained from acclimatized eggs. For the present we recommend the importation of eggs each year but, when the industry is established, eggs should be produced locally.

TABLE VIII.

It will be noticed from the following experiments that the percentage of pebrinized moths from the same lot of eggs of the univoltine broods which were reared in the first part of March, when the temperature of the rearing room varies from 64° to 85° F., is less than in those bred in the latter part of March, when the temperature of the rearing room varies from 70°—90° F. It will be further noticed that the multivoltine Chotopolu and Nistari races reared in the first and latter parts of March exhibited only 3 and 5 per cent pebrinized moths respectively, while the univoltine worms reared outside on trees and domesticated inside exhibited 3 per cent and 16—60 per cent pebrinized moths. The moths from the lot reared outside were healthy, resistant to diseases and admirably suitable for reproductive purposes. It has also been shown that freshly-imported eggs as well as the eggs obtained from the moths acclimatized for two or three years showed an almost equal percentage of pebrine in a climate like Pusa, though we believe that better results can be obtained in cold places like the Hill Stations of Assam, the United Provinces and the Punjab, where worms should be cultivated for reproduction.

We have also shown that good cocoons are similarly obtained from acclimatized eggs if due care and precautions are taken for cellular eggs and if the worms are carefully attended to.

Race.	Date of Hatching.	Date of Mounting.	Weight of 100 pierced cocoons in grains.	Percentage of Pebrinized moths.	Percentage of healthy moths.	Remarks.
Italian-Japanese First Brood.	10-III-14 .	7-IV-14 .	28	21	79	Reared indoors.
Do. . .	10-III-14 .	9-IV-14 .	22·4	3	97	Reared outside on trees.
Italian-Japanese Second Brood.	11-III-14 .	10-IV-14 .	33	29	71	Reared indoors.
Italian-Japanese Fourth Brood.	12-III-14 .	10-IV-14 .	33	19	81	Do.
Italian-Japanese Second Brood.	14-III-14 .	12-IV-14 .	33	57	43	Do.
Chotopolu . . .	9-III-14 .	17-IV-14 .	..	3	97	Do.
Italian-Japanese First Brood.	30-III-14 .	27-IV-14 .	25·2	52	48	Do.
French First Brood . .	31-III-14 .	27-IV-14 .	28	87	13	Do.
Do. . .	31-III-14 .	28-IV-14 .	28	81	19	Do.
Italian First Brood . .	31-III-14 .	29-IV-14 .	25·2	18	72	Do.
Do. . . .	1-IV-14 .	29-IV-14 .	30·8	40	60	Do.
Nistari	21-III-14 .	20-IV-14 .	..	5	95	Do.

TABLE IX.

It will be noticed from the following Table that the univoltine eggs should be kept in cold-storage for about four months, that the temperature suitable for cold storage is about 30°—40° F. and that it is quite possible to preserve the eggs in Hill Stations, such as Shillong, Simla, Naini Tal, etc., where the natural temperature in winter from October to February varies from 60°—30° F., for rearing in February and March, and that for rearing in October or November the eggs should be sent to an ice factory for cold storage, the natural temperature of Hill Stations from May to October being high.

TABLE

Race.	Date of Oviposition.	Date of sending eggs for cold storage.	Date of bringing back the eggs from cold storage.
Univoltine	March 1911	2-V-11	21-X-11
Boropolu	Do.	Do.	Do.
Do.	Do.	..	..
Do.	2-IV-12	15-IV-12	10-X-12
French	June 1911	23-II-12	12-VI-12
French and other Univoltine races	February and March 1912.	15-IV-12	10-X-12
Boropolu	24-III-12	..	..
French	8-IV-12	..	..
Boropolu and other Univoltine races	February and March 1912.	12-VIII-12	24-II-13
Do.	Do.	Do.	26-II-13
Univoltine	27-IV-12	12-VIII-12	26-II-13
Do.	Do.	Do.	24-II-13
Do.	July 1912	30-IX-12	8-III-13
Boropolu and Univoltine races	January to May	30-IV-13	26-X-13
Boropolu	December and April 1913.	..	..
Boropolu and Univoltine races	April and July 1913.	12-IX-13	23-II-14
Do.	Do.	4-X-13	21-II-14
Do.	Do.	17-X-13	21-III-14
Boropolu	7-IV-13	..	..

N. B.—The cold-stored eggs were supplied to many cultivators,

IX—*contd.*

Date of Hatching.	Result of the rearing.	Remarks.
27-X-11. All the eggs hatched in 3 days.	Successful	The eggs were kept at 40°-45° F. in an ice factory.
Do. . . .	Do.	Do.
10-II-12. Almost all the eggs hatched in 8 days.	Do.	The eggs were kept suspended from a ceiling of a room at Pusa the temperature of which varied from 70° to 48° F.
12-X-12. The eggs hatched in 3 days.	Do.	The eggs were preserved at 40°-45° F. in an ice factory.
20-VI-12. The eggs hatched in 3 days.	All the worms died in the 5th stage on account of heat.	Do.
14-X-12. All the eggs hatched in 3 days.	Successful	Do.
7-II-13. The eggs hatched in 10 days.	Do.	The eggs were kept suspended from a ceiling of a room at Pusa the temperature of which varied from 72°-45° F.
10-II-13. The eggs hatched in about 35 days.	The cocoons were small . .	Do.
7-III-13. The eggs hatched in 4 days.	Successful	The eggs were sent to Ramgarh where they were kept suspended in a room the temperature of which varied from 60° to 30° F.
6-III-13. The eggs hatched in 5 days.	Do.	The eggs were sent to Shillong where they were kept suspended from the ceiling of a room the temperature of which varied from 65° to 37° F.
6-III-13. Almost all the eggs hatched in 5 days.	Do.	The eggs were sent to Shillong where they were kept at 60°-37° F.
6-III-13. Almost all the eggs hatched in 4 days.	Do.	The eggs were sent to Muktesar for cold storage.
23-III-13. Almost all the eggs hatched in 4 days.	All the worms died in the 5th stage.	The eggs were sent to Shillong for cold storage.
5-XI-13. Almost all the eggs hatched in 3 days.	Successful	The eggs were sent to an ice factory for cold storage at about 40°-45° F.
5-II-13. The eggs hatched in 9 days.	..	The eggs were preserved in an ordinary room at Pusa.
14-III-14. The eggs hatched in 4 days.	Successful	The eggs were sent to Ramgarh for cold storage.
31-III-14. The eggs hatched in 3 days.	Do.	The eggs were sent to Muktesar for cold storage.
28-III-14. The eggs hatched in 3 days.	Successful. The temperature was mild at Pusa in April this year.	Do.
25-I-14. Almost all the eggs hatched in 8 days.	Successful	The eggs were kept suspended from a ceiling of an ordinary room at Pusa.

almost all of whom obtained satisfactory results.

TABLE X.

The following experiments were undertaken to see whether it is possible and economical to rear the univoltine races by artificial hatching, *i.e.*, (1) by keeping the eggs in a jar of oxygen and (2) and (3) by putting the eggs in concentrated hydrochloric and sulphuric acids and then by washing them in fresh water.

Race.	Date of Oviposition.	Date of stimulus applied.	Kind and duration of stimulus applied.	Number of eggs taken for the experiment.	Number of eggs hatched.	Date of Hatching.
Italian × Japanese	30-1-12	31-I-12	The eggs put in sulphuric acid for 3 minutes.	450	4	18-II-12 to 19-II-12.
Nistari female × Univoltine male. } F_3	22-I-12	2-II-12	The eggs were put in oxygen for 24 hours.	2,000	29	22-II-12 to 10-III-12.
Italian × Japanese	30-I-12	2-II-12	In oxygen for 5 minutes.	1,500	11	18-II-12 to 1-III-12.
Do.	31-I-12	3-II-12	In oxygen for 24 hours.	2,000	88	18 to 29-II-12.
Do.	30-I-12	31-I-12	In concentrated hydrochloric acid for 1½ minutes.	400	*Nil*	

Thus it is apparent that the results obtained by the use of artificial stimuli are not at all satisfactory. Some of the worms, hatched under artificial stimuli, matured but they produced poor cocoons.

TABLE XI.

In this Table the results of crosses between the Indigenous Multivoltine Races are enumerated.

Race.	Generation.	Number of Univoltine layings.	Number of Multivoltine layings.	Date of Oviposition.	Date of Mounting.	Number of empty cocoons without pupal skin per 10 grammes.	REMARKS.
Nistari female × Chotopolu male.	F_1	*Nil*	All	30-IV-14	30-V-14	80	
Do.	F_2	*Nil*	16	9-VI-14	7-VII-14	82	
Do.	F_3	*Nil*	2	19-VII-14	13-VIII-14	80	
Do.	F_4	*Nil*	23	22-VIII-14	19-IX-14	80	
Do.	F_5	*Nil*	13	29-IX-14	2-XI-14	90	
Do.	F_6	12	14	19-XI-14	6-II-15	..	The race is being continued.
Nistari female × Mysore male.	F_1	*Nil*	7	21-VII-14	17-VIII-14	70	
Do.	F_2	*Nil*	All	25-VIII-14	24-IX-14	82	
Do	F_3	38	25	5-X-14	9-XI-14	80	
Do.	F_4	1	13	25-XI-14	..	..	The race is being continued.
Mysore female × Nistari male.	F_1	*Nil*	All	26-VIII-14	25-IX-14	76	*Vide* Table IV.
Do.	F_2	97%	3%	5-X-14	..	..	
Do.	F_3	4½	3½	27-XI-14	..	..	The race is being continued.

PLATE IV.

OUTDOOR REARING IN NETS ON TREES.

From this Table it appears that the crosses between indigenous races yield more silk than pure multivoltine indigenous races at least for some generations. They can be invigorated easily by the introduction of new blood when degeneration sets in in the worms. The conservatism of the cultivators in Bengal against cross-breds should be taken into consideration. The difficulties in this direction can be obviated if multivoltine eggs instead of seed cocoons are distributed to the rearers.

We have seen that close interbreeding, if carried on for a very long time, results in loss of vigour in the worms which spin flimsy cocoons whereas the advantages which follow a cross are visible from the very beginning.

Regarding the improvement of the indigenous multivoltine races by careful selection, we have come to the following conclusions :—

The Nistari and Mysore races yield good cocoons in July to October and in March but these races yield poor silk in mid-winter and mid-summer, though good cocoons are obtained from the same stock if reared in March or April or during the Rains. The Chotopolu yields good silk if reared in October and November. The Bulu, Chinapolu and other races yield very poor silk and should be abandoned. Of all the indigenous races the Mysore race is the best as far as the yield of silk is concerned. Another principle of successful rearing is change of seed after taking two crops in a locality, *i.e.*, importing new stock from distant localities after harvesting one or two crops.

TABLE XII.

We have tried some experiments to see whether it is possible to rear mulberry silkworms on trees in nets or bags of cloth, in order to protect them from sun and rain and from their natural enemies. One branch or two or three branches containing sufficient leaves are selected and are tied together ; next the bag or net is slipped and drawn up until the bottom of the net meets the ends of the branches, care being taken that the branches conveniently fill the bag so that the air in the bag will be allowed to have free play. About fifty worms are deposited on one branch on the fourth or fifth day after hatching, as the newly-hatched worms are too weak to take care of themselves, and then the mouth of the bag is securely tied with a layer of cotton and then with a strong cord at the point of contact with the branches so that ants may not enter. After about twenty or twenty-five days, when the leaves have all been eaten up, the bag is untied and the worms transferred to some fresh branches having sufficient good leaves.[1] The net should be replaced as before. The results are enumerated in the following Table.

[1] This is of course a well-known method of rearing caterpillars and is commonly called "Sleeving." T. B. F.

TABLE XII—*contd.*

Race.	Serial number of nets.	Date of Hatching.	Number of worms placed in net.	Date of the worms placed on tree.	Date of cocoons gathered.	Number of cocoons gathered.	Weight of fresh cocoons in grammes.	REMARKS.
Italian-Japanese	1	10-III-14	45	17-III-14 .	16-IV-14 .	24	34·4	
Do. .	2		50	Do. .	Do. .	47	59·3	
Do. .	3		45	Do. .	Do. .	32	53·1	
Do. .	4		45	Do.	Do. .	17	18·1	
Do. .	5		45	Do.	Do. .	29	34·4	
Do. .	6		45	Do. .	Do.	21	25·0	
Do. .	7		45	Do. .	Do. .	23	25·0	
Do. .	8		45	Do. .	Do. .	33	37·5	
Do. .	9		45	Do. .	Do. .	39	43·7	
Do. .	10		45	Do. .	Do. .	34	46·8	
Do. .	11		45	Do. .	Do. .	24	34·4	
Do. .	12		45	Do .	Do. .	31	50·0	
Do. .	13		45	Do.	Do. .	28	34·4	
Do. .	14		45	Do. .	Do. .	38	50·0	
Do. .	15		45	Do. .	Do. .	9	12·5	
Do. .	16		45	Do. .	Do. .	22	31·2	
Do. .	17		45	Do. .	Do. .	33	34·4	
Do. .	18		45	Do. .	Do. .	21	25·0	
Do. .	19		45	Do. .	Do. .	26	31·2	

Total number of cocoons 531.

Total weight of cocoons 680·4 grammes.

Weight of 531 fresh cocoons of same "eclosion" and race reared in house is 995·6 grammes. The worms of this lot hatched on 10th March 1914 and matured on 9th April 1914.

We have found that the mortality in the worms reared outside on trees from natural enemies is about 38 per cent while that of the worms cultivated inside from diseases is about 10 per cent. The average number of double cocoons reared in nets is 4 per cent and from those reared indoors 7 per cent. The yield of silk from the cocoons reared inside is superior to that of those reared outside; but there is no appreciable difference in lustre, strength, colour and elasticity of the raw silk between the two lots. The moths, which emerged from the cocoons reared outside, were stronger and more resistant to disease than the moths reared inside, the percentage of pebrinized moths from the former

lot being three while that from the latter was 21, so that for reproductive purposes the worms cultivated outside give very satisfactory results.

Rearing in nets was undertaken in August and October 1913 but the majority of the worms died off as the effect of severe rain and cold. The moths, from the few cocoons that were produced, were stronger than those reared indoors.

Conclusions.

(1) Indigenous multivoltine mongrel races yield more silk than pure races but the conservatism of the cultivators against rearing these races will have to be considered in any efforts to introduce them.

(2) Pure multivoltine eggs, obtained from the female moths which have been fertilized by males of the same race produced from a different locality, yield better silk and are more resistant to disease than eggs obtained by crossing the moths of the same locality.

(3) Of all the indigenous races, the Mysore race is the best as far as the yield of silk is concerned. Nistari should be reared in April or May, Mysore race from July to October and univoltine races from October to March.

(4) All races yield more silk if fed with tree mulberry leaves than those fed with bush mulberry leaves.

(5) Imported univoltine eggs should be reared in preference to indigenous races; they can be bred easily in October and February and at any other time when the temperature varies from 65°—85° F. It is better to have one successful univoltine crop in Spring than to have three or four indifferent multivoltine crops.

(6) Imported and acclimatized univoltine eggs can be made to hatch simultaneously in three or four days if the eggs are preserved in hill stations or in an ice factory for about four months.

(7) The percentages of diseased worms from imported eggs and acclimatized univoltine eggs are nearly the same.

(8) For some time univoltine eggs ought to be imported every year from foreign countries and only cold-stored eggs should be distributed to the cultivators.

(9) The cross-breds between Boropolu and foreign univoltine races should be reared in those places where imported foreign races do not thrive well.

(10) The races obtained by crossing Italian and Japanese races yield better results than pure univoltine races.

(11) Univoltine eggs hatched by artificial stimuli do not give satisfactory results.

(12) Worms, reared outside on trees, yield less silk but are more resistant to disease than those bred indoors. The former are admirably suitable for reproductive purposes, but the method of rearing is very expensive.

(13) Multivoltine eggs can be prevented from hatching for about 25 days without injuring the embryos if they are kept in the cold, but the race cannot be improved by this method.

(14) It is possible to get good eggs, which will yield superior cocoons and which will hatch ten or twelve days after oviposition like the multivoltine ones, in all the *Bunds* by a cross between (1) a univoltine male, or (2) a male of a cross between a univoltine male and multivoltine female, or (3) a male of successive generations of this cross and a multivoltine female. The pairing will have to be effected in each generation as the eggs of the second generation of the cross will turn to univoltine. The existing nurseries in Bengal will not be able to meet the demands for eggs and the cultivators may not be able to follow the directions enumerated to produce good eggs.

(15) Our attempts to establish a fixed multivoltine hybrid race which will not degenerate are still being continued.

Advice.

If any doubts arise, reference can always be made to the Imperial Entomologist, Pusa, Bihar, for advice and information, which will be given to inquirers as far as possible.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

Bulletin No. 49 1915

Agricultural Research Institute, Pusa

The experimental error in field trials with sugarcane and the effect on this error of various methods of sampling

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CALCUTTA
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1915

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PREFACE.

I WISH to express my gratitude to Mr. J. W. Leather for kindly reading through the manuscript of this work. I am indebted to him for suggesting the insertion of Table X.

Mr. B. B. Price, my assistant, rendered much help in the field during the taking and weighing of samples.

H. E. ANNETT.

DACCA;

June 20th, 1914.

The experimental error in field trials with sugarcane and the effect on this error of various methods of sampling.

Introduction.

THE subject of experimental error in sampling crops has been dealt with by Bailey [1], Griffin [2], Collins [3], and Wood and Stratton [4].

Mr. Leather in a recent Memoir [5] has produced data showing that the probable error in sampling sugarcane is very small when the sample consists of about 200 canes taken in lots of three from 70 equidistant points throughout a plot.

The opportunity was recently taken at the Dacca Farm of testing this and several other methods of sampling sugarcane plots. Since the experimental plots were triplicated, data have also been obtained which bear on the experimental error to be allowed for in plot trials with sugarcane.

Experimental.

The following five varieties of cane were grown ; Yellow Tanna, Striped Tanna, B 208, B 147, and Dacca Gandari. Each variety was grown on triplicate plots of $\frac{1}{10}$ acre each. Thus there were 15 plots in all of a total area of 1·5 acres.

The arrangement of the plots is shown in the subjoined plan.

Yellow Tanna. I	Striped Tanna. I	B 208 I	B 147 I	Dacca Gandari. I
B 208 II	B 147 II	Dacca Gandari. II	Yellow Tanna. II	Striped Tanna. II
Yellow Tanna. III	Striped Tanna. III	B 208 III	B 147 III	Dacca Gandari. III

[1] *Journal Ind. and Eng. Chem.* I (1909), 161.

[2] *Journal Soc. Chem. Ind.* XXVIII (1909), 192.

[3] *Proc. Univ. of Durham Phil. Soc.* 1908-9, page 129.

[4] *Journal Agric. Sci.* III. page 433 and also four papers published as Supplement No. 7, *Journal Bd. Agric.* Nov. 1911.

[5] *Memoir Dept. of Agric. in India.* Chem. Series. Vol. III. No. IV.

The general treatment of all the plots was uniform. They were sown on the 5th and 6th April 1913, the previous crop having been early rice. No irrigation was given. The whole area was manured as follows :—

Three hundred mds. of cowdung per acre, half on March 20th—25th and half on May 26th—27th, and 20 mds. per acre of castor meal on the 17th and 18th June. There are some slight differences in level over the area and the early growth was not very uniform.

Methods of sampling.

Every endeavour was made to get the work done quickly so that when dealing with any particular plot by various methods of sampling there would be little change in composition of the crop throughout the duration of the experiment.

The sampling methods tested are described below. In this description it is necessary to mention that each plot measured 99 feet by 44 feet and that the rows of cane ran lengthwise through each plot. There were 11 rows in each plot and hence the rows were 4 feet apart and each row was 99 feet long.

(*a*) *Samples consisting of 50 canes taken from 50 points equally distributed over a plot.*

In each of seven plots a peg was put in at every 16 feet interval in each row. The first peg in each row was always put several feet from the end of the row. In this way 5 points were marked in each row or in each plot, 11×5 equal to 55 points. At each point one cane was cut out. The sample obtained in this way therefore consisted of about 50 canes taken from points equally distributed over the whole plot. The theoretical number of 55 canes was not always obtained since if there was a large gap at the point marked by the peg, no cane would be cut there.

(*b*) *Samples consisting of 100 canes taken from 100 points equally distributed over a plot.*

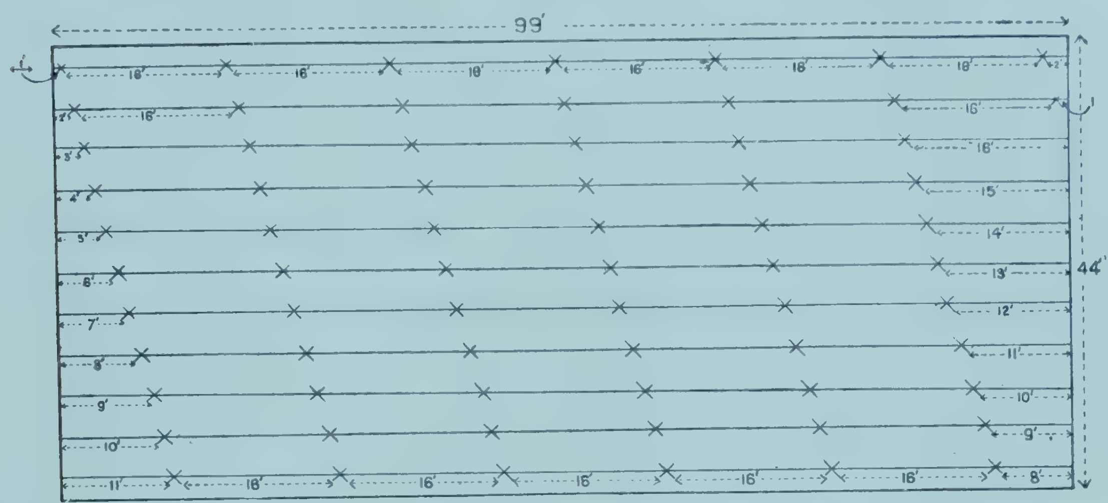
In each of the same seven plots after removal of the above samples pegs were put in each row at 9 feet intervals. There were thus 10 pegs in each row and therefore each plot had 11×10 equal to 110 pegs in all. One cane, the nearest to the peg, was taken at each peg and hence samples consisting of theoretically 100 canes were obtained.

(*c*) *Samples consisting of 200 canes taken in group of three at about 70 equidistant points on each plot.*

After the methods of sampling (*a*) and (*b*) all the plots except Dacca Gandari plot II were sampled as follows. At every 16 feet in each row a peg was put in. Thus 6 or 7 pegs were put in each row since each row was

99 feet long. Hence 66 to 77 points were marked in this way in each plot. The nearest 3 canes to each peg were then cut out and hence each plot gave approximately 200 canes as a sample.

The diagram gives an idea of the procedure in this method of sampling. Each × marks the point at which a peg was driven in the row and the lines represent the rows of cane. In this actual diagram 68 points are marked so the sample would consist of 68 × 3 equal to 204 canes.



(*d*) *Samples consisting of the cane from ½ the plot obtained by cutting alternate rows.*

After samples (*a*), (*b*) and (*c*) had been taken then from each of seven plots every alternate row was cut out and collected as one sample. The remaining alternate rows were taken as a duplicate sample. Each of these duplicates consisted therefore of 5½ rows.

(*e*) *Samples consisting of the cane from half the plot, each sample however being either wholly the eastern or the western half of a plot.*

After sampling as under (*a*), (*b*) and (*c*) then from each of 5 plots all the cane of the eastern half was taken as one sample. That from the western half was taken as its duplicate.

It will thus be seen that methods of sampling (*d*) and (*e*) gave duplicate samples for the plots in which they were carried out.

After sampling, the number of canes in each sample was counted. The whole sample was then weighed and crushed. The juice was weighed and analysed and boiled into *gur*. It has been mentioned above that the 50 cane sample was first taken, then the 100 cane sample and then the 200 cane sample. Finally the ½ plot samples were taken. This procedure was fully carried out only in some of the plots *e.g.*, B. 147, Plots I, II, and III and Dacca Gandari Plots I and III.

In other cases the 100 and 50 cane samples were not taken. Further ½ plot samples were not always taken but after the small samples had been taken the rest of the plot was cut as a whole. In the case of Dacca Gandari, plot II, no sub-samples were taken but the plot cut as a whole.

Reference to the tables (pages 5 to 16) will show clearly the various samples taken from each plot.

In the juice the following determinations were made, specific gravity, reducing sugar, and cane sugar by double polarisation, before and after inversion. From these and the foregoing figures one could then calculate the following data :—

1. Total number of canes per plot.
2. Total weight of cane per plot.
3. Average weight of each cane.
4. Total weight of juice per plot.
5. Percentage of juice to cane on whole plot.
6. Sucrose in juice of whole plot gms. per 100 gms.
7. Reducing sugar in juice of whole plot gms. per 100 gms.
8. Total sugar in juice of whole plot gms. per 100 gms.

Thus we know for each plot all the above data and we are therefore in a position to see clearly the errors involved in the various methods of sampling.

In the accompanying tables all the data obtained are set out.

Since there were triplicate plots of each variety, we shall further have data bearing on the effect of "Soil" factors on the variation and hence of the experimental error involved between various plots on field trials with sugarcane on the Dacca Farm.

Table I.

Date.	Size of sample.	No. of canes.	Total weight of canes. lbs.	Average weight of each cane. lbs.	Total weight of juice. lbs.	Per cent of juice to cane.	Sp. Gr. of juice.	Sucrose gms. per 100 gms. juice.	Reducing sugar gms. per 100 gms. juice.	Total sugar gms. per 100 gms. juice.
				Yellow Tanna Plot I.						
	Whole plot	1,287	3,096·96	2·406	2,17·85	70·34	...	13·95	2·38	16·33
February 1st	½ plot (W. Half)	507	1,314·42	2·592	965·0	73·44	1·069	13·68	2·55	16·23
	Do. (E. Half)	560	1,201·29	2·144	812·0	67·63	1·072	14·29	2·23	16·52
January 30th	200 cane sample	220	581·25	2·642	401·5	69·08	1·070	13·89	2·27	16·16
				Yellow Tanna Plot II.						
	Whole plot	1,506	3,612·72	2·399	2,871·0	79·47	...	14·65	2·26	16·91
February 2nd	½ plot (W. Half)	660	1,498·00	2·270	1,337·0	89·25	1·076	14·59	2·17	16·76
	Do. (E. Half)	620	1,471·38	2·375	1,100·2	74·78	1·072	14·79	2·37	17·16
January 30th	200 cane sample	226	643·25	2·847	433·7	67·43	1·072	14·52	2·29	16·81
				Yellow Tanna Plot III.						
	Whole plot	1,071	2,352·40	2·197	1,554·5	66·08	...	14·29	2·09	16·38
February 2nd	½ plot (W. Half)	350	702·46	2·007	467·5	66·55	1·072	14·72	1·72	16·44
	Do. (E. Half)	510	1,134·44	2·224	740·2	65·25	1·074	14·15	2·26	16·41
January 30th	200 cane sample	211	515·50	2·443	346·7	67·27	1·071	14·02	2·24	16·26

Table II.

Date.	Size of sample.	No. of canes.	Total weight of canes. lbs.	Average weight of each cane. lbs.	Total weight of juice. lbs.	Per cent of juice to cane.	Sp. Gr. of juice.	Sucrose gms. per 100 gms. juice.	Reducing sugar gms. per 100 gms. juice.	Total sugar gms. per 100 gms. juice.
				Striped Tanna Plot I.						
	Whole plot	1,235	2,915·48	2·360	2,151·2	73·78	...	13·02	2·73	15·75
February 3rd .	½ plot alt. rows sample No. I .	460	1,185·34	2·577	810·0	68·34	1·068	13·15	2·93	16·08
	Do. sample No. II . . .	560	1,087·64	1·942	911·5	83·80	1·068	13·01	2·52	15·53
January 31st .	200 cane sample . . .	215	642·50	2·988	429·7	66·90	1·067	12·78	2·82	15·60
				Striped Tanna Plot II.						
	Whole plot	1,330	3,884·27	2·920	2,642·2	69·05	...	12·64	3·20	15·84
February 4th .	½ plot alt. rows sample No. I .	590	1,709·37	2·897	1,273·5	74·50	1·068	12·58	3·23	15·81
	Do. sample No. II .	530	1,485·15	2·802	883·0	59·66	1·068	12·79	3·29	16·08
January 31st .	200 cane sample . . .	210	689·75	3·284	482·7	70·00	1·066	12·51	2·98	15·49
				Striped Tanna Plot III.						
	Whole plot	1,131	3,227·01	2·853	2,23[illegible]·0	69·10	...	12·66	2·99	15·65
February 4th .	½ plot alt. rows sample No. I .	430	1,203·34	2·800	824·2	69·50	1·067	12·90	2·81	15·71
,, 5th .	Do. sample No. II . . .	500	1,350·42	2·701	937·7	69·44	1·068	12·55	3·09	15·64
January 30th .	200 cane sample . . .	201	673·25	3·350	470·0	69·81	1·068	12·47	3·0[illegible]	15·56

Table III.

Date.	Size of sample.	No. of canes.	Total weight of canes. lbs.	Average weight of each cane. lbs.	Total weight of juice. lbs.	Per cent of juice to cane.	Sp. Gr. of juice.	Sucrose gms. per 100 gms. juice.	Reducing sugar gms. per 100 gms. juice.	Total sugar gms. per 100 gms. juice.
				B 208 Plot I.						
	Whole plot	1,082	1,154·42	1·067	761·7	65·99	...	17·90	1·00	18·90
February 5th .	½ plot alt. rows sample No. I .	340	450·48	1·325	294·5	65·37	1·082	17·47	0·98	18·45
	Do. do. do. No. II .	541	412·84	0·763	270·0	65·39	1·083	18·26	1·02	19·28
January 31st .	200 Cane sample . . .	201	291·00	1·398	197·2	67·78	1·083	18·04	1·02	19·06
				B 208 Plot II.						
	Whole plot	1,075	1,130·32	1·051	704·5	62·33	...	19·28	0·80	20·08
February 6th .	Whole plot less sample . .	760	794·00	1·045	481·5	60·64	1·089	19·32	0·81	20·13
	200 cane sample	180	178·96	0·994	118·5	66·24	1·086	19·82	0·75	20·07
„ 5th .	100 cane sample	90	112·11	1·246	74·0	66·01	1·084	18·99	0·85	19·84
	50 cane sample	45	45·25	1·005	30·5	67·40	1·086	19·32	0·67	19·99
				B 208 Plot III.						
	Whole plot	1,047	1,315·75	1,257	878·7	66·79	...	18·69	0·80	19·49
February 6th .	Whole plot less sample . .	720	859·00	1·193	565·5	65·83	1·084	18·54	0·83	19·37
	200 cane sample	170	230·75	1·357	155·2	67·28	1·086	19·14	0·65	19·79
	100 cane sample	100	153·00	1·530	102·5	67·00	1·086	19·10	0·81	19·91
	50 cane sample	57	73·00	1·281	55·5	76·03	1·083	18·15	0·83	18·98

Table IV.

Date.	Size of sample.	No. of canes.	Total weight of canes. lbs.	Average weight of each cane. lbs.	Total weight of juice. lbs.	Per cent of juice to cane.	Sp. Gr. of juice.	Sucrose gms. per 100 gms. juice.	Reducing sugar gms. juice.	Total sugar gms. per 100 gms. juice.
					B 147 Plot I.					
	Whole plot	1,436	2,681·00	1·869	1,463·5	54·53	...	16·67	1·60	18·27
February 9th	½ plot alt. rows sample No. I	502	937·00	1·867	359·0	38·31	1·077	16·64	1·57	18·21
	Do. sample No. II	560	1,005·50	1·796	681·5	67·78	1·080	16·74	1·58	18·32
	200 cane sample	217	437·00	2·014	211·0	48·28	1·079	16·69	1·60	18·29
	100 cane sample	107	200·00	1,869	138·0	69·00	1·079	16·55	1·71	18·26
	50 cane sample	50	104·50	2·090	74·0	70·81	1·079	16·31	1·71	18·02
					B 147 Plot II.					
	Whole plot	787	1,395·00	1·773	991·7	71·09	...	16·92	1·32	18·24
February 7th	½ plot alt. rows sample No. I	290	470·00	1·621	347·5	73·83	1·079	17·03	1·36	18·39
	Do. sample No. II	210	357·00	1·700	245·2	68·70	1·077	16·97	1·33	18·30
	200 cane sample	167	340·25	2·038	235·2	69·14	1·079	16·70	1·31	18·01
	100 cane sample	71	129·25	1·820	94·5	73·11	1·079	16·92	1·16	18·08
	50 cane sample	49	98·50	2·010	69·2	70·30	1·079	16·87	1·39	18·26
					B 147 Plot III.					
	Whole plot	1,696	3,117·00	1·838	2,144·7	68·81	...	15·83	1·97	17·80
February 10th	½ plot alt. rows sample No. I	630	1,167·75	1·853	838·0	71·76	1·076	15·80	1·95	17·75
	Do. sample No. II	710	1·162·50	1·637	785·5	67·57	1·077	15·88	1·99	17·87
	200 cane sample	208	482·75	2·321	351·7	72·86	1·077	15·78	1·96	17·74
	100 cane sample	98	191·50	1·954	137·7	71·93	1·077	15·67	2·00	17·67
	50 cane sample	50	112·50	2·250	31·7	28·22	1·079	16·33	1·83	18·16

Table V.

Date.	Size of sample.	No. of canes.	Total weight of canes. lbs.	Average weight of each cane. lbs.	Total weight of juice. lbs.	Per cent of juice to cane.	Sp. Gr. of juice.	Sucrose gms. per 100 gms. juice.	Reducing sugar gms. per 100 gms. juice.	Total sugar gms. per 100 gms. juice.
			Dacca Gandari Plot I.							
	Whole plot .	1,794	1,653·50	0·922	1,147·0	69·37	...	14·75	2·39	17·14
February 11th .	½ plot West ½ .	780	676·00	0·867	469·5	69·45	1·075	14·70	2·44	17·14
	½ plot East ½ .	620	578·00	0·932	399·5	69·12	1·075	14·64	2·39	17·03
	200 canes .	228	227·25	0·997	157·2	69·19	1·078	15·14	2·24	17·38
	100 canes .	110	111·25	1·011	77·2	69·44	1·077	14·71	2·47	17·18
	50 canes .	56	61·00	1·089	43·5	71·31	1·077	14·97	2·26	17·23
			Dacca Gandari Plot II.							
February 11th .	Whole plot .	1,280	1,264·75	0·988	839·2	66·36	1·079	15·89	2·24	18·13
			Dacca Gandari Plot III.							
	Whole plot .	1,302	1,533·25	1·178	1,094·5	71·38	...	13·84	2·52	16·36
February 11th .	½ plot West ½ .	440	598·00	1·360	430·5	72·00	1·072	13·84	2·48	16·32
	½ plot East ½ .	470	455·00	0·948	319·5	70·22	1·072	13·51	2·66	16·17
February 12th .	200 canes	210	256·25	1·220	184·2	71·90	1·073	14·07	2·46	16·53
	100 canes	130	153·50	1·180	109·2	71·17	1·074	14·04	2·54	16·58
	50 canes .	52	70·50	1·356	51·0	72·34	1·075	14·70	2·07	16·77

Discussion of the results obtained.

The tables are self explanatory. They are so designed as to set out all particulars of the various samples taken. In every case from these figures the corresponding figures have been calculated for the whole crop and are set out in the tables. We can thus compare each of our samples with the figures for the whole plot and thus see at a glance the error involved in each of the methods of sampling. The only errors occurring in these calculated figures for the whole plot are :—

(1) Those due to the error of chemical analysis including specific gravity determination. In work of this nature these may be taken as inappreciable.

(2) Errors in weighment of cane and juice. Since all weighments were taken to within $\frac{1}{4}$ lb. this source of error is also inappreciable, as most of the weighments taken ran into hundreds of pounds.

Sugar percentage.

In the accompanying table are set out the amounts in gms. sugar per 100 gms. juice by which each sample differed from the actual *amount* of sugar calculated to be present in the juice of each whole plot.

Table

Departure from actual value of whole plot

—		SUCROSE.						
		Size of sample.						
		50 canes.	100 canes.	200 canes.	½ plot E.	½ plot W.	½ plot alt. rows Sample I.	½ plot alt. rows Sample II.
Yellow Tanna	Plot I.	...	...	−0·06	+0·34	−0·27	...	...
	II.	...	...	−0·13	+0·14	−0·06	...	...
	III.	...	...	−0·27	−0·14	+0·43	...	...
Striped Tanna	I.	...	...	−0·24	...	...	+0·13	−0·01
	II.	...	...	−0·13	...	...	−0·06	+0·15
	III.	...	...	−0·19	...	...	+0·24	−0·11
B 208	I.	...	...	+0·14	...	...	−0·43	+0·36
	II.	+0·04	−0·29	+0·04	...	+0·04*		...
	III.	−0·54	+0·41	+0·45	...	−0·15*		...
B 147	I.	−0·36	−0·12	+0·02	...	...	−0·03	+0·07
	II.	−0·05	...	−0·22	...	...	+0·11	+0·05
	III.	+0·50	−0·16	−0·05	...	...	−0·03	+0·05
Dacca Gandari	I.	+0·22	−0·04	+0·39	−0·11	−0·05	...	...
	II.	...	...	...	...	...	...	...
	III.	+0·86	+0·20	+0·23	−0·33	...	...	...

VI.

in gms. sugar per 100 gms. juice.

REDUCING SUGAR.							TOTAL SUGAR.						
SIZE OF SAMPLE.							SIZE OF SAMPLE.						
50 canes.	100 canes.	200 canes.	½ plot E.	½ plot W.	½ plot alt. rows Sample I.	½ plot alt. rows Sample II.	50 canes.	100 canes.	200 canes.	½ plot E.	½ plot W.	½ plot alt. rows Sample I.	½ plot alt. rows Sample II.
...	...	−0·11	−0·15	+0·17	...	...	...	...	−0·17	+0·19	−0·10	...	...
...	...	+0·03	+0·11	−0·09	...	...	...	...	+0·10	+0·25	−0·15	...	...
...	...	+0·15	+0·17	−0·37	...	...	...	...	−0·12	+0·03	+0·06	...	...
...	...	+0·09	...	...	+0·20	−0·21	...	...	−0·15	...	...	+0·33	−0·22
...	...	−0·22	...	...	+0·09	+0·03	...	...	−0·35	...	...	−0·03	+0·24
...	...	+0·10	...	...	−0·18	+0·10	...	...	−0·09	...	...	+0·06	+0·01
...	...	+0·02	...	...	−0·02	+0·02	...	...	+0·16	...	...	−0·45	+0·38
−0·13	+0·05	−0·05	...	+0·01*	...	...	−0·09	−0·24	−0·01	...	+0·05*		...
+0·03	+0·01	−0·15	...	+0·03*	...	...	−0·51	+0·42	+0·30	...	−0·12*		...
+0·11	+0·11	...	...	...	−0·03	−0·02	−0·25	−0·01	+0·02	...	...	−0·06	+0·05
+0·07	−0·16	−0·01	...	...	+0·04	+0·01	+0·02	−0·16	−0·23	...	...	+0·15	+0·06
−0·14	+0·03	−0·01	...	...	−0·02	+0·02	+0·36	−0·13	−0·06	...	...	−0·05	+0·07
−0·13	+0·08	−0·15	...	+0·05	...	...	+0·09	+0·04	+0·24	−0·11	...	...	...
...	...	...	...	...	...	...	...		...	...	...	...	...
−0·45	+0·02	−0·06	+0·14	−0·04	...	...	+0·41	+0·22	+0·17	−0·19	−0·04	...	...

* Whole plot less other samples.

A sufficient number of samples has not been taken to enable me to calculate the probable error involved in sampling by each method but the next table gives the maximum *plus* or *minus* departures from the real value in the case of each method of sampling.

Table VII.

Maximum plus *and* minus *departure from actual value.*

Size of sample.	Sucrose, gms. per 100 gms. juice.	Reducing sugar, gms. per 100 gms. juice.	Total sugar, gms. per 100 gms. juice.
50 canes	−0·54 to + 0·86	−0·45 to + 0·11	−0·51 to + 0·41
100 canes	−0·29 to + 0·41	−0·16 to + 0·11	−0·24 to + 0·42
200 canes	−0·27 to + 0·45	−0·22 to + 0·15	−0·35 to + 0·30
Half plot E.	−0·33 to + 0·34	−0·15 to + 0·17	−0·19 to + 0·25
Half plot W.	−0·27 to + 0·43	−0·37 to + 0·17	−0·15 to + 0·06
Do. alternate rows sample No. I	−0·43 to + 0·24	−0·18 to + 0·20	−0·45 to + 0·33
Do. do. sample No. II	−0·11 to + 0·36	−0·21 to + 0·10	−0·22 to + 0·38

It is obvious from the table that when the sample consists of only 50 canes one is liable to very considerable errors.

The next table gives the mean *minus* and the mean *plus* departures from the actual for each method of sampling. We again see that the sample consisting of only 50 canes gives the largest error but there is not much to choose between the other methods of sampling.

Table VIII.

Mean minus *and* plus *departures from actual gms. sugar per 100 gms. juice.*

Size of sample.	Sucrose.	Reducing sugar.	Total sugar.
50 canes	−0·32 + 0·40	−0·21 + 0·07	−0·28 + 0·22
100 canes	−0·12 + 0·20	−0·16 + 0·05	−0·13 + 0·17
200 canes	−0·16 + 0·21	−0·08 + 0·06	−0·14 + 0·18
Half plot E	−0·19 + 0·24	−0·07 + 0·10	−0·15 + 0·16
Half plot W	−0·09 + 0·21	−0·17 + 0·11	−0·07 + 0·03
Half plot alternate rows sample No. I	−0·14 + 0·16	−0·06 + 0·11	−0·15 + 0·18
Do. sample No. II	−0·06 + 0·13	−0·11 + 0·09	−0·11 + 0·16

Juice extraction.

We may now turn to the errors in the figures for juice extraction as effected by various sampling methods.

These errors are set out in the following table which has been compiled from tables I to V.

Table IX.

Juice extraction : Departure from actual value of whole plot.

—	Size of sample.						
	50 canes.	100 canes.	200 canes.	½ plot E.	½ plot W.	½ plot alternate rows Sample I	½ plot alternate rows Sample II.
Yellow Tanna—							
Plot I	...	...	−1·26	−2·71	+3·10	...	...
Plot II . . .	...	...	−12·04	−4·69	+9·78	...	...
Plot III . . .	...	...	+1·19	−0·83	+0·47	...	...
Striped Tanna—							
Plot I	...	...	−6·88	...	...	−5·44	+10·02
Plot II . . .	...	...	+0·95	...	...	+5·45	−9·39
Plot III . . .	...	...	+0·71	...	...	−0·60	+0·34
B 208—							
Plot I	...	...	+1·79	...	...	−0·62	−0·60
Plot II . . .	+5·07	+3·68	+3·91	...	−1·69*		...
Plot III . . .	+9·24	+0·21	+0·49	...	−0·96*		...
B 147—							
Plot I	+16·28	+14·47	−6·25	...	...	−16·22	+13·25
Plot II . . .	−0·79	+2·02	−1·95	...	...	+2·74	−2·39
Plot III . . .	−40·59	+3·12	+4·05	...	...	+2·95	−1·24
Dacca Gandari—							
Plot I	−1·94	+0·07	−0·18	−0·25	+0·08	...	...
Plot III . . .	+0·96	−0·21	+0·52	−1·16	+0·62	...	...

* Whole plot less other samples.

An inspection of the table shows that when the sample consists of only 50 canes one is liable to an extremely large error in the figure for juice extraction. There is not much difference in the error introduced in the other methods of sampling though in the half plot samples, the alternate row system does not seem to give such good results as the division into two compact halves, which was unexpected.

Mr. Leather has however suggested to me the following means of comparing the half plot systems of sampling. In each case there are duplicates, that is, the one half is supposed to be equal to the other half. In the case of the East and West plots there might be a systematic difference due to soil, but the data show that such difference did not occur. In such cases of duplicate samples it is best to compare the differences between each pair. These have been taken out from Tables I to V and they are as follows :—

Table X.

Differences between duplicates.

——	Variety and plot.	Weight of cane.	Sucrose.	Glucose.	Juice. Per cent.
East and West half plot samples.	Yellow Tanna—				
	Plot I	0·448	0·61	0·32	5·81
	Plot II	0·105	0·20	0·20	14·47
	Plot III	0·217	0·57	0·54	1·30
	Dacca Gandari—				
	Plot I	0·065	0·06	0·05	0·33
	Plot III	0·412	0·33	0·18	1·78
		1·247	1·77	1·29	23·69
Mean .	....	0·249	0·35	0·26	4·74
Alternate row samples.	Striped Tanna—				
	Plot I	0·635	0·14	0·41	15·46
	Plot II	0·095	0·21	0·06	14·84
	Plot III	0·099	0·35	0·28	0·94
	B 208—				
	Plot I	0·562	0·79	0·04	0·02
	B 147—				
	Plot I	0·071	0·10	0·01	29·47
	Plot II	0·079	0·06	0·03	5·13
	Plot III	0·216	0·08	0·04	4·19
		1·757	1·73	0·87	70·05
Mean .	....	0·251	0·25	0·12	10·10

From the mean difference under each head one can form a good opinion of the relative merits of each system of sampling. Judged by the weight

of cane the methods are equally good ; the sucrose and glucose tests would show the "alternate row" method to be the better, whilst the juice percentage would show the East and West method to be the better. The latter result is however largely due to the data from B 147 plot I which gave 38·31 per cent. against 67·78 per cent. juice in duplicate samples. This difference shows that there was some unusual cause operative.

Weight of individual canes.

In the table below are set out the *minus* or *plus* departure from the actual value in lbs. of the weight of the individual canes as derived by the various methods of sampling.

Table XI.

Weight of individual canes. Departures from actual value for whole plot in lbs.

——	SIZE OF SAMPLE.						
	50 canes.	100 canes.	200 canes.	½ plot E.	½ plot W.	½ plot alternate rows Sample No. I.	½ plot alternate rows Sample No. II.
Yellow Tanna—							
Plot I	...	...	+0·236	−0·262	+0·186	...	...
Plot II	...	...	+0·448	−0·024	−0·129	...	...
Plot III	...	...	+0·246	+0·027	−0·190	...	...
Striped Tanna—							
Plot I	...	...	+0·628	...	...	+0·217	−0·418
Plot II	...	...	+0·364	...	...	−0·023	−0·118
Plot III	...	...	+0·497	...	...	−0·053	−0·152
B 208—							
Plot I	...	...	+0·331	...	...	+0·258	−0·304
Plot II	−0·046	+0·195	−0·057	...	−0·006 *		...
Plot III	+0·024	+0·273	+0·100	...	−0·064 *		...
B 147—							
Plot I	+0·221	...	+0·145	...	...	−0·002	−0·073
Plot II	+0·237	+0·047	+0·265	...	...	−0·152	−0·073
Plot III	+0·412	+0·116	+0·483	...	...	+0·015	−0·201
Dacca Gandari—							
Plot I	+0·167	+0·089	+0·075	+0·010	−0·055	...	...
Plot III	+0·178	+0·002	+0·042	−0·230	+0·182	...	...

* Whole plot less other samples.

The most noticeable point about this table is the fact that the small samples even up to 200 canes give almost constantly high results for the weight of the individual cane.

Effect of soil factors on variation.

It will be remembered that each of the five varieties was grown on triplicate plots which were uniformly distributed over the whole experimental area (see diagram on p. 3).

Any variation between the same variety sown on those triplicate plots may be considered due to soil factors.

In the table below, the figures for sucrose, reducing sugar and total sugar in gms. per 100 gms. juice are collected together for all the plots :—

——	Sucrose.	Reducing sugar.	Total sugar.
Yellow Tanna—			
Plot I	13·95	2·38	16·33
Plot II	14·65	2·26	16·91
Plot III	14·29	2·09	16·38
Striped Tanna—			
Plot I	13·02	2·73	15·75
Plot II	12·64	3·20	15·84
Plot III	12·66	2·99	15·65
B 208—			
Plot I	17·90	1·00	18·90
Plot II	19·28	0·80	20·08
Plot III	18·69	0·80	19·49
B 147—			
Plot I	16·67	1·60	18·27
Plot II	16·92	1·32	18·24
Plot III	15·83	1·97	17·80
Dacca Gandari—			
Plot I	14·75	2·39	17·14
Plot II	15·89	2·24	18·13
Plot III	13·84	2·52	16·36

The variation in composition of the same variety of cane sown on neighbouring plots is therefore very considerable. The variation is much greater than any error which has been introduced by any of the methods of sampling I have tested in the experiments.

Data such as these are of importance in that they give an idea of the magnitude of the experimental error which must be allowed for in field trials on a series of sugarcane plots.

In the case of Yellow Tanna the variation between the plots in the case of sucrose amounts to 0·70 gms. per 100 gms. juice and in the case of total sugar 0·58 gms. per 100 gms. juice, about 5 and 3·5 per cent. respectively. With Striped Tanna the sucrose variation is 0·38 and the total sugar 0·19 gms. per 100 gms. juice or about 3·1 and 1·2 per cent. respectively.

In B 208 we meet with greater variation, for the sucrose variation is 1·38 and the total sugar 1·18 gms. per 100 gms. juice or 7 and 6 per cent. respectively.

B 147 shows a variation in sucrose of 1·09 and of total sugar 0·47 gms. per 100 gms. juice, percentages of 7 and 2½ respectively.

Finally Dacca Gandari shows a variation in sucrose of 2·05 and of total sugar 1·77 gms. per 100 gms. juice or percentages of 14 and 10 respectively.

These results show that a very large experimental error has to be allowed for in field trials over a series of sugarcane plots.

If one, moreover, turns to the total weight of cane obtained on the plots one sees an enormous variation among the triplicate plots. In B 147 for instance plot III gave 3,117 lbs. of cane against 1,395 lbs. in plot II. In the Striped Tanna variety, plot I gave 2,915 lbs. of cane as compared with 3,884 lbs. on plot II.

Hence on the Dacca Farm with such enormous differences between triplicate plots considerable error must be expected in any plot experiments with sugar cane.

At the same time in these experiments if the varieties grown were judged by any of the plots for sugar percentage in juice the order of merit would be—

B 208.

B 147.

Dacca Gandari or Yellow Tanna.

Striped Tanna.

There would thus be a doubt between Dacca Gandari and Yellow Tanna.

It must here be remarked that the laterite soil of the Dacca Farm shows great lack of uniformity over quite small areas.

Conclusions.

1. The results of these experiments confirm those of Mr. Leather in that in sampling a field of sugarcane the following method gives very accurate results. The sample should consist of about 200 canes taken in

groups of three from about 70 places throughout the area. These 70 places should be accurately measured out and the three canes nearest to the measured points be taken, provided such canes are canes which would normally be taken by the cultivator for juice extraction.

2. No increase in accuracy seems to be obtained by taking half plot samples.

3. In these experiments the "100 canes" samples seem to have given as good results as any other method of sampling, but samples consisting of only 50 canes are much less reliable.

4. Data have been obtained bearing on the experimental error which must be allowed for in field experiments with sugarcane in a series of plots. The results naturally only strictly apply to experiments on the laterite soil of which the Dacca Farm soil is a type. This soil shows much more than the usual lack of uniformity.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

Bulletin No. 50 1915

Agricultural Research Institute, Pusa

The Improvement of Tobacco Cultivation in Bihar

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

AGENTS FOR THE SALE OF BOOKS

PUBLISHED BY THE

Superintendent Government Printing, India, Calcutta.

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CONTENTS.

THE IMPROVEMENT OF TOBACCO CULTIVATION IN BIHAR.

1. Introduction.

THE importance of rapid, uniform growth in the case of tobacco in Bihar cannot be overestimated. The crop is transplanted on the *hathia* rains, about the end of September, and has to reach its maximum development by the middle of December, when the weather ordinarily becomes too cold for further growth. The ripening process is completed by the end of January and curing is carried through before the advent of the hot, dry west winds in March. The growth of the crop has to be completed in two months—from the middle of October, when the young plants are established, till the middle of December when growth is checked by the cold. Any late set out plants, which miss this period of growth, are always behind the rest and invariably give a diminished yield. Further, their presence renders the product un-uniform and the fields cannot be cut and cured at one time. While everything points to the necessity of establishing the transplanted seedlings at the end of September, and of raising a uniform crop so as to take the fullest advantage of the warm weather of October and November, it is nevertheless true that a regular field of tobacco in Bihar is the exception rather than the rule. This want of uniformity arises, partly from the defective methods of raising and transplanting the seedlings and partly from the mixing of varieties. In these matters, the local agriculture is particularly defective.

In the course of the work on tobacco breeding at Pusa, it became necessary to discover a method of growing even cultures of this crop and to eliminate, as far as possible, all want of uniformity in growth due to irregularities of soil and methods of planting. In this work, the defects in the local practice had to be overcome and the labour employed had to be taught improved methods. Some of these improvements are so simple and so inexpensive that they can easily be adopted on indigo estates and also by the ryots themselves. Others, on the other hand, are too elaborate for general use and are of importance only

in plant-breeding work at an experiment station. In the present paper, attention has been drawn mainly to those improvements, which can at once be adopted on the large scale in Bihar. The details relating to experiment station work are dealt with in the footnotes in smaller type.

A study of the various efforts, which have been made in the past to improve the production of Indian tobacco, brings out one great defect which applies to almost all the schemes on record. In nearly every case, attempts have been made to improve the curing of tobacco and for this purpose curers have several times been imported from America. In other cases, the schemes have been still more ambitious and have attempted the production of bright yellow tobacco by some method of flue-curing or of wrapper leaves for cigars. These two latter products—flue-cured tobacco and cigar wrappers—represent the highest point which tobacco production has hitherto reached in any region and the attempt to produce them brings India into competition with countries like the United States where great energy, enterprise and abundant capital are directed by men possessing an intimate knowledge of the plant and of the manifold needs of the trade. Further, in America, the tobacco trade is well organized in every direction, well known grades for all sorts of produce have been established and a market exists for dealing with the product. Importing countries, like Great Britain, can be certain of obtaining regularly the raw material for their tobacco factories in large quantities and of standard grade. In India, on the other hand, the tobacco trade is quite different. The growers are often relatively poor men with small capital and of limited outlook. The trade, for the most part, is concerned with the primitive needs of India, and, except for the production of cheroots in parts of Madras and Burma, the mass of the tobacco grown is consumed in India by the people themselves. There are hardly any Indian agencies at present which could handle expensively cured tobacco and ensure regular supplies, true to grade, for importing countries like Great Britain. A little consideration must show that the older Indian schemes of tobacco improvement have been too ambitious and have not taken into consideration the present conditions of production and distribution. Further, until the ryot can show that he can grow uniform crops of those varieties, most suited for the various grades required by the trade, it is doubtful whether it is worth while spending time and money on expensive curing methods. It is a sounder policy to begin at the other end and to improve the methods of growing tobacco and so obtain a higher yield of uniform produce. This is the first step in the work and the foundation for future improvements which will be possible only when the trade becomes better

organized and when buying agencies are set up which can deal with an improved product. Some of the cigarette-manufacturing companies now established in India, such as the Peninsular Tobacco Company at Monghyr and those corporations associated with this undertaking, might easily extend their operations and buy up Indian leaf for export. The possibility of progress in the Indian tobacco trade is increasing and a step in advance can be made provided the ryot can be shown how to improve his practice and grow a product worth curing for the export trade. Much, however, can be done immediately by showing the Indian grower how to increase the yield of his present crop and how to ensure it in unfavourable years. This is the first obstacle to be overcome in the long and difficult road which must be traversed before the tobacco trade in India can think of entering the European market.

2. The Raising of the Seedlings.

In all countries where tobacco cultivation has developed beyond the primitive condition, the greatest care is taken in the preparation and management of the seed-beds. This care is necessary on account of the small size of the seed and the fact that the amount of reserve material in the embryo is very small. From a very early stage, the young tobacco plant has to lead an independent existence and is compelled to make its own food just as in the case of mature plants.[1] From this it follows that several conditions are essential if the seedlings are to thrive and grow rapidly in the seed-bed stage. These are :—

(*a*) Large, heavy seeds which contain the maximum amount of reserve material possible.

(*b*) Well manured seed-beds in such a condition that an abundant supply of mineral food materials is immediately available for the seedlings.

(*c*) An adequate supply of moisture for the young plants. This condition is best realized by adding materially to the organic matter in the soil and so increasing its water-holding capacity.

(*d*) Well aerated soil so that there is a full supply of oxygen for the germinating seeds and developing roots.

(*e*) Efficient drainage.—This can best be obtained by raising the seed-beds and providing shallow trenches between the beds to carry off the surplus rain water.

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[1] This explains why the growth of the tobacco seedlings is so slow at first. At this stage, growth is naturally limited by the rate at which the small seedlings can manufacture food.

These ideal conditions for the tobacco seedlings cannot be realized without adequate and timely preparation. A high-lying piece of land must be selected well above the flood level and so situated that surface drainage is easy. It should be well broken up during the preceding hot weather and afterwards cultivated and kept free from weeds. At the beginning of the monsoon, a large quantity of well rotted organic matter, such as old indigo *seeth* or leaf mould, should be added to the soil and afterwards well-mixed. If, in addition, rape or castor-cake is available, the future seed-beds should receive a good dressing of these substances during the early rains. By these means, a rich garden earth is obtained and there is ample time for the manure to decay and get thoroughly incorporated with the soil before the seed is sown during the first half of August.

Before sowing, the land should be well and deeply cultivated and then thrown up into beds, slightly raised towards the centre, separated by trenches about two feet wide and four inches deep. The trenches drain the seed beds and also serve as paths for subsequent weeding and thinning. The breadth of the beds should be about four to five feet as this distance allows the whole surface to be reached from the side without treading on the bed itself. The seed should be mixed with well sifted wood ashes and the mixture should be evenly distributed over the bed. The surface is then slightly raked over to cover the seed and the whole compressed with the *kurpi*, the soil being afterwards roughened with the hands. Care should be taken not to bury the seeds too deeply as all such seeds do not germinate until they are subsequently brought up to the surface. The seed rate should be adjusted so that a good even stand of plants is obtained without the labour of excessive thinning afterwards. When the second pair of leaves is developed, the surface of the seed bed should be lightly broken with a pointed bamboo peg, about the size of a lead pencil, and, as the plants increase in size, a little fresh earth from an unsown seed bed should be sprinkled on the surface from time to time. The addition of this fresh earth to the surface of the bed is very important and serves to replace any soil lost by rain wash and also supports and strengthens the young plants, particularly if the seed beds have to be watered. Two thinnings are usually required, and, after the second one, the plants should stand about two inches apart. Weeds of course should be removed from time to time but the real secret of raising good tobacco seedlings is to keep the surface crust (*papri*) broken, to add new earth as the plants grow, particularly if the beds are washed by heavy rain, and to keep them properly spaced. In this way strong, stocky plants are obtained which are able to stand the shock of

PLATE I.

STERILIZED SEED BEDS.

transplanting with not more than two per cent. of casualties. The importance of raising strong, healthy and well spaced plants can hardly be overestimated. From such plants, a far better crop is raised and there are far fewer deaths than when crowded, drawn and weakly plants are used for establishing the crop.

The strength of the seedlings can be increased if the seed-beds are partially sterilized by heat before the tobacco seed is sown. The best results at Pusa so far have been obtained by heating the upper three inches of the soil in an iron pan, the fire being laid underneath the pan. In this way about six inches of the surface soil is heated. The resulting seedlings grow much faster than those on unheated beds and also faster than those grown on beds which have been heated by burning rubbish on the surface only. The difference obtained in these two methods of soil sterilization is shown in Plate I opposite. The seedlings on sterilized beds are always larger and stronger than those obtained on unheated beds and moreover are ready for transplanting considerably earlier.

There is one seed-bed trouble in Bihar which should be mentioned, namely, the damping off of the seedlings in years of long continued and heavy rainfall subsequent to sowing. The beds then become sour, the seedlings do not grow and the fungus which causes this disease rapidly destroys the whole bed. The disease is particularly destructive if partially decayed organic matter has been used for the seed beds and if insufficient time has been given for the organic matter to decay before sowing the seed. Should the disease appear and the seedlings begin todie off in circular patches, the whole seed-bed should be broken up with a bamboo pricker and the beds should be mulched with *ordinary* earth. This neutralises the sour condition of the soil and arrests the disease. It is better, however, to avoid it altogether int he manner indicated above. If the month of August is particularly wet, the ryots in Bihar lose their early sowings almost as a matter of course and there is a great dearth of plants at the end of September. In such years as the present, 1914, the tobacco fields are particularly uneven, there is a large proportion of late fields, and, for this portion of the crop, the growing period has been missed. In such years, there has never been any failure of the seed-beds in the Botanical area at Pusa, a result which proves the value of the methods advocated in this section. The details described above may appear trivial and unimportant to the casual reader, who has not raised a tobacco crop in Bihar, but they are essential if progress is to be made in tobacco production in this region.

3. Planting out.

Much of the unevenness of the tobacco fields in Bihar is due to the want of care in taking out the plants from the nursery at planting time. The plants are pulled up by hand, and, in the process, practically all the young roots are destroyed. It is only to be expected that so many do not stand the shock of transplanting and die off in great numbers after lingering for a day or two in the hot fields.

This loss of plants can easily be avoided. About three hours before the plants are taken from the seedbeds, a pointed skewer, either of bamboo or iron, about the thickness of a lead pencil should be pushed into the seed-bed to a depth of about three inches at intervals of every three or four inches. The beds should then be well watered and left for about three hours during which the water percolates evenly through the bed. The plants should then be taken out by means of a long narrow *kurpi* with as little damage to the roots as possible. Removed in this way, each plant has a large ball of earth adhering to the roots and it is to facilitate removal in this manner that correct spacing of the plants in the seed-beds is so important. The plants should be laid on bamboo trays, made like the lid of a basket, and carried in this way to the field. They should be planted firmly and deeply and at once watered. Planting should be done in the evening and the following morning the young plants should be again watered and covered for the first two days, during the day only, with the leaves of the *nim* tree (*Melia indica*).[1] On the third morning, the *papri* round the young plants should be broken and the surface left rough. After this, the plants will establish and not more than one in a hundred should need replacing. The vacancies should be at once filled up by new plants from the nursery and one replacement should be sufficient.

In years when the *hathia* rains fail, more difficulty is experienced in establishing the tobacco crop as the moisture in the surface soil is not so abundant. Some form of furrow irrigation, by which the plants can be watered without destroying the tilth, is then a great advantage. Such a method has been worked out at Pusa and has already

[1] In plant breeding work with tobacco where it is important to establish the crop evenly and to avoid, as far as possible, all replacement, it is best to cover the plants during the day with a small perforated saucer (*dhakna*) made of baked clay. These are merely saucers with the base removed and measure nine inches in diameter and are two inches deep. The hole in the base is about four inches in diameter. By inverting these perforated saucers over the young plant it is completely protected from the sun. At night, they are removed to give the plant the full benefit of the dew. In this way, a transplanted tobacco never flags even at midday and the plants rapidly establish themselves.

PLATE II.

FURROW-IRRIGATION AT PUSA.

been described.[1] After the final preparation of the field, furrows, about 18 inches wide and 4 inches deep, are laid off at the proper distance, so that there will be a furrow between alternate rows of tobacco (see Plate II). The furrows are then filled several times from a distributing channel which runs at right angles to the rows. The water percolates laterally and soon the soil is well moistened between the furrows. Transplanting is now carried on in the soil, moistened by lateral seepage from the trenches, and the young plants are covered with *nim* leaves during the day for the first two days. No direct watering is now necessary at planting and thus the labour in establishing the crop is reduced. The check due to transplanting by this method is very small and the plants quickly establish themselves. The loss due to transplanting in 1908 at Pusa, a year of exceedingly short moisture, was about 1 in 200.

4. Cultivation.

The main object of cultivation is to give the tobacco plant a loose soil into which the young rootlets can easily and quickly penetrate. The tap root is broken in transplanting, and, in consequence, the plant tends to become surface rooted and to develop a mass of fibrous roots. These require a loose, well-aerated, fertile soil for their maximum development, and, for this reason, tobacco does not thrive, and indeed is rarely planted, on heavy, impermeable and waterlogged land.

The high-lying tobacco lands in Bihar can be greatly improved by surface drainage.[2] In this way the fine soil is retained, local waterlogging is prevented, the low places are rapidly filled up with silt carried from the higher areas and the fields soon level themselves naturally. Waterlogged areas in the tobacco fields are now common and these can be detected by the small, yellow, stunted plants which grow on such spots. Drainage, by carrying off the surplus water, soon removes the cause of this trouble and also helps in the aeration of the fields. The retention on the fields of the fine particles of soil, which are now largely removed by rain wash and carried to the rice lands, maintains the water-holding capacity and fertility of the high lands and tends to reduce the amount of added organic matter necessary for the tobacco crop. The importance of surface drainage in tobacco growing in Bihar was well shown on the Dholi Estate in 1914 in the case of some sloping fields

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[1] Howard & Howard, *Mem. of the Dept. of Agr. in India* (*Botanical Series*), Vol. III, p. 76, 1910.

[2] See *Pusa Bulletin* No. 33 and *Agr. Jour. of India*, Vol. IX, p. 197, 1914.

previously greatly damaged by rain wash. As soon as these fields were drained and the loss of fine soil prevented, the ryots at once took them up for tobacco and were ready to pay high rents to the factory for their use. Before they were drained, it had been impossible to rent these fields at all and they gave a very poor return of cheap crops like oats. Similar cases of enhanced rental following surface drainage have occurred on the Doulutpur Estate.

The after cultivation of the tobacco plant is of great importance, and, in this respect, the ocal practice is quite effective. Unless the soil is frequently stirred, the tobacco plants do not grow rapidly and also become yellow and unhealthy. After rain especially, when a surface crust has been formed on the soil, this stirring with the *kurpi* is most necessary. As soon as the soil is given a new supply of air by the surface cultivation, growth begins again and the plants take on, in a day or two, the dark green appearance characteristic of a thriving tobacco crop. This result explains why it is so important to pay so much attention to the cultivation of the tobacco plant. Tobacco is a rapid grower and requires a large amount of air in the soil for the use of the growing roots. If this air supply is interfered with, either by waterlogging in the monsoon, by deficient surface cultivation afterwards or by the formation of a *papri* by rain in October or November, the growth is at once affected and it is difficult to resist the conclusion that the tobacco crop is partly limited by the air-supply in the soil.

In a crop which has to grow so rapidly as tobacco, it is almost unnecessary to say that clean weeding is essential. As far as this can be carried out, the fields are kept free from weeds during the early monsoon but in the management of a tobacco fallow the country plough is a poor thing. The bullock power required is great, considering the slowness of the work. The five-tine spring-tooth cultivator, which is now in use on some indigo estates, is admirably adapted for the summer fallowing of tobacco lands. The work done is at least four times that of the country plough and the bullock power required is not appreciably greater than that required by one wooden plough. It is no exaggeration to say that by the use of these cultivators in maintaining a clean summer fallow in the early monsoon, the efficiency of the available cattle power is multiplied by three.

There is one important weed which is not influenced by cultivation, however thorough this may be carried out. This is the leafless parasite known as the *tokra* (*Orobanche*) which is found towards the end of the season, as the plants ripen, in great numbers attached to the roots and growing up through the soil round the

tobacco plants. As these parasites are destitute of green colouring matter, they are unable to make their own food like ordinary green plants but derive all their nourishment from the tobacco plant itself. In this way they diminish the yield as they use up much of the food required by the tobacco to ripen the leaves. These parasites grow from seeds which are produced by the ripe *tokra* in abundance and which live for years in the soil. The only way to reduce this pest is to collect and destroy the *tokra* before the seeds are formed and also to give up the practice of growing the second crop. This second crop is of small value and is a wretched bargain from the estate point of view. By its presence, the *tokra* plants increase enormously and the seed left in the soil infests it thoroughly for years to come. The land also tends to become foul from weeds and the great advantage of a deep, long-continued hot weather cultivation is largely lost. Even if the rents paid for the tobacco land on indigo estates have to be reduced, it would be good policy to stop all second cuts and to plough up the fields as soon as the first crop is taken off. In agriculture, the best investment of capital is to maintain the soil in a high condition and to allow nothing to interfere with this. The money obtained from a second tobacco crop is bad finance as it sacrifices the future for a small temporary advantage.

Topping. When cigarette tobacco is desired, the leaves must not be so large as those grown by the ordinary Bihar methods. By topping the plants when about two feet high, the number of leaves is increased and their size diminished. As soon as the bunch of young flowers at the growing point can easily be grasped by the hand, they should be removed together with one or two small leaves. In this way, the stem grows to about thirty inches in height and all the leaves are nearly the same size. This naturally gives a uniform product and any tendency to excessive coarseness is prevented.

5. Manuring.

Organic matter is essential in Bihar if a large and well ripened crop of tobacco is to be obtained. On this central fact the system of manuring depends. In the absence of organic matter, growth is very slow and is not completed before the cold weather sets in. The organic matter can be applied in any form such as farmyard manure, cowdung, oilcake or indigo refuse (*seeth*), but in all cases it is good practice to apply the manure early in the monsoon so as to give time

for it to decay and to become thoroughly incorporated with the soil. The best manure for tobacco for the local trade is undoubtedly *seeth* and no form of organic matter tried at Pusa is so effective as this in producing rapid growth and the maximum possible yield. *Seeth* seems to have a manurial value apart from its chemical composition. The explanation is to be found, in all probability, in the fact that the small twigs aerate the soil and so supply the much-needed oxygen to the roots of the tobacco in sufficient quantities. It is probable, however, that the planters apply this manure to the tobacco lands in needlessly large amounts and that a very good result could be obtained by half the quantity now given. With the decline of the indigo industry, the amount of *seeth* available is getting less every year so that the question of *seeth* substitutes for tobacco and for the high lands generally will have to be considered.

A considerable amount of attention has been devoted at Pusa to green-manuring for tobacco by means of *sanai* (*Crotalaria juncea*) and excellent crops have been obtained by means of this manure only. The matter has been dealt with in detail in other papers [1] and need only be summarized here. Green-manuring with *sanai* for tobacco should only be attempted on *light, high-lying, well-drained soils,* and should never be tried, except for rice, on heavy land. The crop should be ploughed in not later than the middle of July and it will probably be found an advantage to cut it and leave it on the surface for a week or so before ploughing in. The time factor is most important. The Pusa experiments show quite conclusively that the green crop requires two months to decay and if this period is extended or reduced the yield of tobacco is materially affected (see Plate III). On heavy lands or on lands which are waterlogged from any cause, green-manuring leads to a smaller crop than that on control plots. Shortening the time between ploughing in the green manure and planting the next crop gives reduced yields similar to those on heavy or waterlogged land. That these results are, in all probability, connected with the supply of oxygen in the soil, is suggested by the effects obtained last year at Pusa in sub-soiling after green-manuring. Three plots were green-manured with *sanai* on July 15th, August 7th, and August 28th, respectively. On September 24th, a strip down the middle of these plots was sub-soiled to a depth of

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[1] Howard and Howard, *Agr. Jour. of India,* Vol. VII, p. 79, 1912, and Vol. IX, p. 201, 1914.

PLATE III.

TOBACCO GREEN-MANURED WITH SANAI.

about twelve inches, two days before the tobacco was transplanted. The arrangement of the plots is shown in the following diagram :—

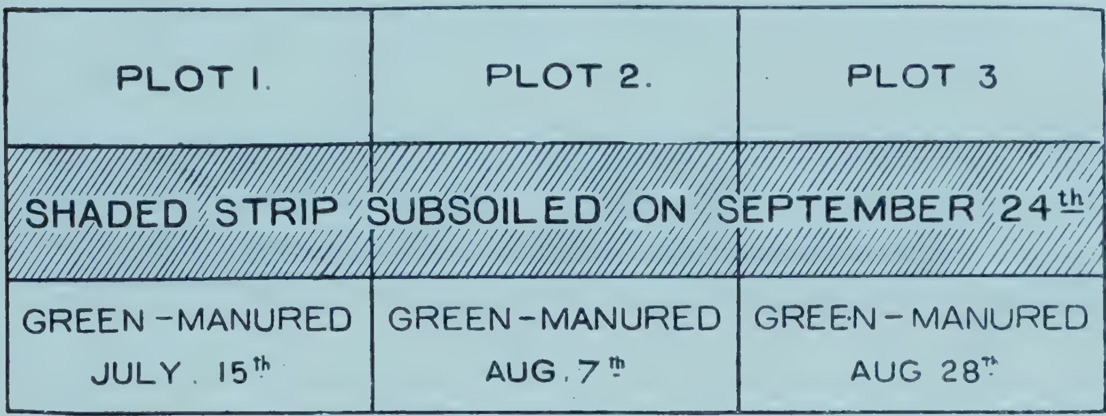

FIG. 1. GREEN-MANURING EXPERIMENT AT PUSA IN 1913.

The results of the experiment were very striking. The tobacco in plot 1 grew very rapidly from the beginning and gave the best results. Plot 2 was not so good while plot 3 was poor. In all the plots, subsoiling gave a considerable crop increase and the appearance of the tobacco on this strip suggested a liberal dressing of nitrogenous manure. The sub-soiling would have released a portion of the carbon dioxide in the soil which had accumulated as a result of the green-manuring and would also have directly increased the supply of oxygen. Possibly the extra air supply not only influenced the final stages in the nitrification of the decaying organic matter but also increased the supply of air for the roots of the tobacco crop. The changes in the soil gases following green-manuring under Indian conditions obviously require to be investigated and the results are almost certain to prove of interest. Besides the time-factor, it is exceedingly probable that thorough cultivation, after the green crop has for the most part disappeared, will be necessary if optimum results are to be obtained. The large amount of carbon dioxide resulting from the decay of the green crop[1] will probably have to be got rid of and as much oxygen as possible introduced into the soil before the tobacco is transplanted.

Although very good results can be obtained with *sanai* by itself as a manure for tobacco on properly drained land, nevertheless there is one defect which should be noticed. Tobacco grown after *sanai* alone does

[1] Kidd, *Proc. Roy. Soc.*, B., Vol. 87, 1914.

not ripen off as sharply and evenly as tobacco grown after *seeth* or farm-yard manure. The results suggest that the materials supplied by *sanai* are not quite sufficient for the needs of the crop. Its value can probably be increased, either by supplementing it with a light dressing of *seeth* or superphosphate or both. Work on these lines is in progress at Pusa.

In addition to the forms of organic matter described above, there is one indirect method of manuring in Bihar which is of the greatest importance to the tobacco crop and also to the maintenance of the fertility of the high-lying lands. This is the *rahar* crop (*Cajanus indicus*) which should precede tobacco whenever practicable. In addition to the benefits conferred by *rahar* in virtue of the action of its root nodules, this crop adds largely to the organic matter in the soil by the fall of its leaves and flowers during the cold season. In addition, the deep root system breaks up the subsoil and acts as an efficient subsoiler. This crop is also dug over during the cold weather and after harvest the surface is left rough and free from weeds. With a little extra manure, *rahar* is an excellent preparation for tobacco.

6. Uniformity of Type.

The number of different varieties of tobacco in cultivation in India is very great. These vary much among themselves in cropping power and suitability for growth in any particular tract. In striving for the maximum yield, it is essential to grow one high-yielding variety only and not have fields containing many sorts varying greatly in cropping power. One sort only should be grown, and, in places where the crop is mixed, the elimination of all unsuitable kinds and the retention of one type only would in itself constitute an improvement. For the local trade in Bihar, it would pay to take more trouble in keeping the sorts separate so as to raise fields even in all respects as regards size and shape of leaf, time of ripening and texture and colour of the cured product. If progress is ever made in India in tobacco growing, and the product is exported, the uniformity of the type will become of the first importance.

Cross-fertilization between the varieties is common in tobacco. There is however no loss of vigour when this is prevented and it is easy to maintain unimpaired any particular type by means of self-fertilized seed. These facts have to be considered in organizing the seed supply of any improved kind of tobacco in Bihar. If left to itself, the new kind will cross with the local sorts and in a few years the improvement will be lost.

THE PRODUCTION OF SELF-FERTILIZED SEEDS.

The prevention of crossing in tobacco is easy. Before the first flower opens, the whole of the inflorescence should be enclosed in an ordinary muslin meatsafe and any flowering suckers which arise below the netted portion of the plant should be pinched off. The plant flowers and sets seed inside the netting and by this means crossing is prevented. The arrangements at Pusa for raising large quantities of self-fertilized seed for distribution are shown in Plate IV.

In the United States and other countries where tobacco cultivation has been developed, great care is taken to separate all light seed and to sow only the heaviest seed. A marked improvement in uniformity results from this and it has been arranged to treat all the tobacco seed issued from Pusa in this way. The heavy, well-ripened seeds contain the maximum possible reserve material and thus give the young seedlings the best chance of success in the seed-bed.

7. Cigarette Tobacco in Bihar.

During recent years, a demand has arisen in Bihar for a variety of tobacco suitable for the manufacture of cigarettes. A large factory has been started at Monghyr and a subsidiary Company is at work at Dalsingh Sarai in connection with the purchase and curing of raw tobacco to supply the Monghyr factory. The ordinary Bihar crop is much too rank and coarse for cigarette manufacture. The woody midrib of the leaf, after passing through the cutting machines, yields sections too hard and too large for the purpose which perforate the cigarette paper. Further, this heavy tobacco is deficient in texture and there is insufficient elasticity in the cut-product to make it usable for cigarettes. The colour of the cured leaf is also too dark.

At the request of the Peninsular Tobacco Company, a good deal of work has been done at Pusa in the search for a suitable cigarette tobacco for Bihar. Seed from all the chief tobacco localities in India was collected and the types found in this seed have been separated in pure culture and classified. The results of this work were published in a previous paper.[1] All the likely types of this collection were grown at Pusa and cured both on racks in the sun and also on the ground. Large samples of the cured product were sent to the factory and actually made into cigarettes. At the same time, a number of American

[1] Howard and Howard, *Mem. of the Dept. of Agr. in India* (*Botanical Series*), Vol. III, No. 2, 1910.

varieties,[1] suitable for cigarettes, were also grown and tested in a similar way. In this work we have been greatly indebted to Mr. R. C. Harrison, now Director of the Indian Leaf Tobacco Development Company, for numerous reports on the samples of tobacco produced at Pusa.

The results of these numerous trials were somewhat unexpected. All the American varieties proved unsuitable as they did not grow fast enough in Bihar to have the least chance of success with the cultivators. In all cases, the seedlings were weak and lagged behind the more robust Indian forms. The Americans were about a week to ten days late in transplanting and this slowness of growth was also seen in the ripening process. All the introduced kinds were too late for Bihar. As regards the colour, texture and flavour of the American sorts, the results were disappointing and in no case was a variety found combining the requisite colour, texture and flavour for cigarette manufacture.

The Indian varieties gave much more promising results. Many of the Bihar kinds gave good colour and flavour, when cured on racks, but all were deficient in texture. Only one, out of all the fifty-one Indian types grown at Pusa, showed itself to possess the desired combination of texture and flavour with a fair colour when cured on racks or on the ground. This was Type 28, a kind found in a sample of seed from South Bihar. This variety has given good results for several years both on racks and also when cured on the ground. On the large scale, under estate conditions, it has done exceedingly well and a great demand for seed has arisen not only in Bihar but also in other parts of India. Type 28 has also been taken up by the people for the local trade as they find that, topped low in the country fashion, it gives a heavy yield of produce.

Ripening of tobacco. One of the principal factors in the valuation of cigarette tobacco is colour. A bright yellow colour in the cured leaf is the chief aim of the grower. In order to obtain this in practice, it is essential that the leaf should be fully ripe and contain as little green colouring matter as possible. The ripening process in the tobacco plant consists in the deposition of starch in the leaf and in the gradual elimination of the green colouring matter. This makes the leaf thicker, and, when the plant is fully ripe, the leaves are so brittle that they snap easily when folded between the fingers. Brown flecks also appear in the leaves as ripening proceeds. The ripening process should be complete by the end of January so that there is no stimula-

[1] The American varieties tried were—Burley, Long-leaf Gooch, White-stem Oronoko, Easter Pride, Conqueror and Granville.

tion to new growth when the temperature begins to rise in February. The season therefore imposes very definite limits for cigarette tobacco in Bihar. All growth in size must be completed by about the middle of December when the temperature falls. During the cold weather, the ripening process should take place and the crop should be cut by the end of January. Late planted tobacco or tobacco which has not been adequately manured does not complete its growth by the middle of December. The cold weather merely arrests growth which, in such crops, begins again as soon as the temperature rises in early February. Afterwards, the tendency to more growth is greatly stimulated by the heat, the plants endeavour to make suckers and cannot be induced to ripen off sharply. These facts show how important it is in high class tobacco-growing so to manage the crop that it suits the season to the best advantage.

Principles of curing. The principles underlying the curing of tobacco are simple.[1] The details of the process are variously modified to suit the requirements of the numerous classes of tobacco. When the ripe plant is cut and hung up in the air, a starvation process begins in which the starch in the leaf is gradually consumed. If the leaf is killed by bruising or by too rapid drying, the starch is not removed sufficiently and the resulting tobacco is lifeless and harsh to the feel. This partly explains why ground-cured Bihar tobaccos are not suitable for cigarette purposes. The leaf has no elasticity and when cut will not tend to swell out and fill the cigarette paper. In the air-curing process, besides the consumption of the starch, another series of changes is proceeding. The green colour slowly disappears and the complete yellowing of the leaves marks the first stage in the death of the plant. The next stage in the process is the change from yellow to brown due to oxidation. The moister the leaf the more rapid is this change and if it is allowed to proceed far enough, the colour changes to a very dark hue or to black. For cigarettes, the more this brown colour develops the lower the value of the product. When the yellow stage in curing is reached, the midrib of the leaf still contains a good deal of moisture and this has to be removed by drying, otherwise the leaves will not stand transport and will not be in a suitable condition for treatment in the drying machine at Dalsingh Sarai. The problem in Bihar is to remove the moisture in the midrib without developing the brown colour and to do this in the cheapest and simplest way.

[1] For further details see Garner, *Bulletin 143, Bureau of Plant Industry*, U. S. Dept. of Agr., 1909, and Odlum, *The Culture of Tobacco*, Dept. of Agr., Southern Rhodesia, 1905.

Rack-curing. The method adopted at Pusa to obtain the best yellow tobacco is that known as rack-curing or sun-curing. The process was suggested by the Peninsular Tobacco Company as being the most suitable for the conditions in Bihar. As is well known, the easiest method of obtaining cigarette tobacco is by flue-curing in barns but the local conditions in Bihar put such an expensive process out of the question. In rack-curing, the stems of the ripe plants, while still standing in the field, are split with a knife nearly to the ground and are then cut down. After standing a short time to wilt, the plants are inverted and slung on bamboo sticks about five feet long so that they just touch one another sideways. The loaded sticks are then carried to the bamboo racks where they are placed in position. The tips of the leaves should be a foot above the ground and the loaded sticks should be arranged on the racks so that the plants on each stick just hang free from the next. This allows of sufficient space for drying and for the circulation of air. The racks should be provided with a grass roof to keep off the dew and protect the drying plants from rain and hail. The crop is allowed to hang till the midribs of the leaves are dry and this can easily be tested by bending the leaf between the fingers. If the midrib snaps, the leaf is dry enough. After drying, the plants are taken down and stripped, the leaves being tied together in bundles in the ordinary way. There must be sufficient moisture in the leaf for handling and for this reason it is best to get the drying done before the onset of the west winds, otherwise it is often too dry to get the tobacco into condition for stripping and baling. The leaves should be baled with as little moisture as possible, and at once sent to the factory at Dalsingh Sarai for passing through the drying machine previous to bulking.

The disadvantages of this method of curing are obvious. A considerable amount of labour and expense are involved in the erection of the curing racks. The curing process is a long one and the crop is on the racks for at least six weeks, during which it is liable to damage by wind, rain and hail. Towards the end of the process, the danger of fire has to be guarded against. A good deal of supervision is required when the cured plants are taken off the racks and the leaves are stripped and baled. If the plants are too moist, there is a danger of the development of the brown colour as well as heating in the bales on the way to the factory. If the crop is taken down too dry, there is a great loss of leaf by breakage.

From the economic point of view also there are obvious drawbacks in rack-curing. There is only one purchaser for this class of product,

namely, the factory, as the local dealers do not require rack-cured tobacco. It is clear therefore that no estate should go in for this product except under a satisfactory contract with the Company whose advice and assistance in the matter should be enlisted.

Among the numerous varieties rack-cured at Pusa, by far the best results were obtained with Type 28 and these results have been since repeated on the large scale at Doulutpore and other factories.

Ground-curing. A good deal of attention has been paid at Pusa to finding some simple modification of the ordinary ground-curing method by which a product can be obtained more suitable for cigarette manufacture, than ordinary Bihar tobacco. Colour is of minor importance in the local trade and frequently no pains are taken in the local curing to obtain a light coloured leaf. It has been found at Pusa that, if all the operations in ground-curing are carried out with the least possible amount of moisture, a very fair colour is obtained combined with a good texture and flavour. Whenever the tobacco is spread out to dry, it should be bulked again *as soon as the plants can be handled.* It must never be allowed to get wet with the moist night dews, otherwise the light colour is lost. This modification is possible on a large scale, provided the extra care and supervision are suitably rewarded by an enhanced price.

A large number of types have been cured on the ground by the above method and the produce has been made into cigarettes. The best reports were always obtained by Type 28 so that this tobacco is obviously most suited for cigarette purposes whether cured on racks or on the ground. In 1911, Mr. Harrison reported on Type 28, cured on the ground, as follows :—

"All four lots exceptionally good, texture very good, colour good and very good for cigarette purposes. No. 28 is considered by the writer to be the best variety sent to us this year." (Report dated April 8th, 1911).

The following year this tobacco, cured on the ground, obtained the following report :—

" Colour bright and texture above the average of Indian Tobacco with regard to small stems and fibre. We think this particular type of tobacco will make a very fair smoke as a cigarette. " (Letter dated April 19th, 1912). As Type 28 yields as much as the local, an advantage would be obtained by growing this kind. The difficulty here is again the want of competition. Ground-cured Type 28 in the best form for cigarettes is not so suitable for the Indian trade as the same tobacco

grown and cured in the local way. In this case also, a contract or agreement with the Company is essential before this kind is taken up on the large scale for cigarette purposes.

Seed supply of Type 28. A large quantity of seed of Type 28 is grown at Pusa every year for distribution and steps are taken to prevent cross-fertilization. Applications for seed should be sent to the Imperial Economic Botanist at Pusa before the end of March, when this and other *rabi* seeds are distributed. About one table-spoonful of seed is required for an acre of land so that five *chittacks* of seed are sufficient for ten acres.

8. Summary.

The conclusions reached in this paper can be summarized as follows :—

1. The small size of the tobacco seed and the fact that it contains a small amount of reserve material necessitate great care in the preparation and manuring of the seed-beds.

2. The rate of growth of the seedlings is increased by frequently breaking the surface of the beds, by the addition of fresh earth and by thinning.

3. There is no danger of the seedlings damping off provided the seed-beds have been properly prepared. If this disease appears in improperly prepared beds, it can be checked by cultivation and mulching with *ordinary* earth.

4. The spacing of the seedlings in the seed-beds is most important so that strong, stocky plants may be obtained. Weak, crowded and drawn seedlings do not stand the transplanting process well.

5. In transplanting, the plants should be taken up with balls of earth, and for this purpose the time and method of watering the seed-beds are important.

6. In dry years when the *hathia* fails, the crop can be readily established by furrow irrigation. By this means even in the driest years the casualties should not exceed one per cent.

7. The real object of cultivation in the case of tobacco is to supply the roots with abundant air in such a manner that the moisture is not lost.

8. The damage done by the *tokra* can be minimized by giving up the second crop, a practice which also interferes with hot weather cultivation.

9. Organic matter in sufficient amount is essential for the tobacco crop. Indigo *seeth* is the best manure. *Sanai* is to some extent a *seeth* substitute provided the crop is only grown on high-lying, well drained lands and provided the after cultivation is sufficient to aerate the ground thoroughly before the tobacco is planted.

10. As far as possible, tobacco should follow *rahar* as this latter is an excellent preparation for tobacco.

11. Cross-fertilization is common in tobacco so that the seed of any improved variety introduced into Bihar will have to be raised under bag.

12. Large, heavy seed gives better results than light, badly grown seed.

13. The best cigarette tobacco yet tried at Pusa is an Indian tobacco, Type 28, which when cured on racks or on the ground has given the best results.

14. Seed of Type 28 can be obtained in quantity at Pusa.

15. The importance of growing only one kind of tobacco and of growing this kind in such a manner that even fields are produced is very great.

PUSA;
November 28, 1914.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 51 1915

Agricultural Research Institute, Pusa

First Report on the Improvement of Indigo in Bihar

(With notes on Drainage and on Green-Manuring)

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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First Report on the Improvement of Indigo in Bihar

(With notes on Drainage and on Green-manuring.)

I. Introduction.

A LARGE amount of attention has been devoted, in the past, both by Government and by the Planters, to the improvement of the indigo industry in Bihar. [1] Investigations have been in progress during the last fourteen years with the object of increasing the yield of indigo per acre and thereby assisting the industry to meet the competition of the synthetic product. These various investigations are well known and therefore need not be referred to in detail now. A full account is to be found in the papers of Rawson, Bergtheil, Bloxam, Leake and Parnell, while Watt, in the *Dictionary of Economic Products of India* and in the *Commercial Products of India,* has dealt with the various aspects of the indigo industry in India. The student of Indian agricultural science will be able to trace the literature on this subject by referring to the writings of Watt for the earlier papers and to the reports of the Sirsiah Experiment Station for the most recent investigations. Previous workers have dealt almost exclusively with the chemistry of the manufacturing process, but some attention has been paid to the botanical aspect. Beyond various manurial experiments, very little work has been done on the purely agricultural side of the question and on the physiological aspect of the rôle of the indigo-producing principle in the economy of the plant.

A study of the past work on indigo reveals the fact that the most important advance which has been made during the last fourteen years was the introduction of a new species of *Indigofera* (*I. arrecta,* Hochst.) from Java. This species is now commonly known in Bihar as Java indigo, a plant originally found growing wild in Natal. Java indigo was introduced into

[1] From the beginning of 1898 to the end of 1913 the sum of £54,207 has been expended on indigo research work in Bihar. Of this large sum £32,052 has been contributed by Government, the remaining £22,155 by the Bihar Planters' Association.

Bihar in 1898 by Mr. H. A. Bailey, who found on visiting Java in that year that the Dutch planters had discarded their original indigo (*I. oligosperma*), commonly known as Guatemala indigo, in favour of one from Natal. From the time of the original introduction into Bihar, the cultivation of Java indigo spread very considerably and in 1909-10 exceeded the area under ordinary Bihar indigo (*I. Sumatrana* Gaertn). Since 1910, the area under Java indigo has decreased from 70,000 to about 15,000 bighas in 1913. During this period the area under Sumatrana has remained constant at about 45,000 bighas a year.

The present position of the indigo investigations in India is as follows : The Indigo Research Station at Sirsiah was closed on March 31st, 1913, and the staff dispersed. The reasons which led to this decision are dealt with in detail in the Sirsiah Report for 1912-13. Briefly stated, it was found that Java indigo could not be induced to form seed at Sirsiah and, in consequence, the selection work on this crop, which formed the main item of the programme of investigation, was interfered with to such an extent that no hopes of any successful results could any longer be entertained. The Bihar Planters' Association wisely decided to close the station and to ask the Imperial Government to continue the work. The Planters agreed to the offer of the Government of India that the indigo investigations should be transferred to the Botanical Section of the Pusa Institute, and, since March 31st, 1913, we have been in charge of the work.

The causes of the non-success of the Sirsiah experiments with Java indigo have been put down to a diseased condition of the plant. In the last Sirsiah report this matter is referred to as follows by Parnell :—

" The term ' disease ' has been applied for lack of a more definite term to a certain unhealthy condition of the seed-plant which will now be considered.

" Up till about 1909, with few exceptions, Java indigo gave excellent crops of seed in Bihar, averaging about 10 to 12 maunds an acre on good soils. In 1910, the seed-plant in many places largely died out and in 1911 almost the whole seed crop of Bihar was a failure. Although in places the 1912 crop appears to have been slightly better, the same condition holds, that however healthy a crop may appear, even up to the flowering time, it is impossible to say whether it will produce seed or not.

" The incidence and course of the disease are as follows :—

" Some time in August or September, or even later in some cases, a number of plants begin to alter in appearance ; their lower leaves become

of a greyish slaty colour and feel harsh and crisp to the touch and generally become somewhat folded longitudinally. This condition spreads gradually upwards and the older leaves drop off till there is nothing but a small bunch of stunted leaves at the tip of each branch. The growing point may remain alive and produce tiny leaves for a time, but finally it dies and the branch gradually dies backwards often producing small shoots with minute leaves which die off successively. The whole plant is not always affected, in fact occasionally half the plant or even only one branch may remain perfectly healthy and produce seed after all the rest is dead. It is common for a plant that is quite dead above to produce a number of very strong healthy shoots from the lower main stem, but in almost every case these die off later. In advanced stages it is common for healthy shoots on a diseased branch to wilt suddenly and die even before the main branch has actually died back to the junction. This may be due to the action of saprophytic fungi that have gained access to the dead part of the main branch and worked back to the point of junction.

"Practically without exception it is the oldest growths that first show signs of disease. This holds good whether one compares plant sown in October with February sowings, the latter with July sowings *moorhun* with *koonti* (*i.e.* first with second growth), second with third growth, the main stem with its side branches, or the old lower branches with the young upper ones. In all the above pairs representing growths of different ages the former older growth is affected more than the later younger respectively.

"Up to the present time no explanation of this diseased condition has been found. After a fruitless examination and consideration of the matter at Sirsiah the aid of the Imperial Department of Agriculture was obtained.

"Mr. Lefroy, Imperial Entomologist, in the *Agricultural Journal of India*, Vol. VIII, Part I of January 1913, gives his results and expresses his conviction that the diseased condition is not due to nor in any way connected with the insect pest *Psylla*, nor to any other insect.

"Mr. Butler, Imperial Mycologist, and Mr. Shaw, Supernumerary Mycologist, have made a very thorough examination of the disease and report that it cannot be attributed to any definite fungus.

"Mr. Hutchinson, Imperial [Agricultural] Bacteriologist, reports that so far his investigations have given no indication of bacterial disease and he considers that further work will probably confirm this result.

"Mr. Howard, Imperial Economic Botanist, in *Bulletin No. 33 of Agricultural Research Institute, Pusa,* considers that the diseased condition

B 2

is due to a combination of bad cultivation and water-logging of the soil."

Our investigations have confirmed the position taken up in *Pusa Bulletin* No. 33. All the evidence obtained so far goes to show that the unhealthy condition of Java indigo, grown for seed, follows from a water-logged condition of the soil, aggravated in many cases by defective cultivation, using this term in the sense of general crop management. We have further discovered a method of growing Java indigo for seed in Bihar which avoids the diseased condition referred to above, and a careful consideration of this method will confirm our views as to the causes of the original trouble.

On taking up the indigo investigations in the beginning of 1913, the industry presented three problems for immediate solution. In the first place, some method of growing Java indigo for seed was most urgent. Without a supply of well-grown seed, at a moderate cost, the industry was in danger of collapse. The second question referred to improvements in the management of the crop so as to ensure two cuts of leaf at least and to save the large losses due to the wilting and unhealthy condition of the crop which ensues after the first cutting in July. Thirdly, the question of the improvement of the crop by selection and the discovery of the methods to be adopted in this work seemed an urgent matter in view of all the circumstances of the industry. In the following pages will be found an account of our investigations on these various matters, together with our views as to future work on indigo.

II. The Growth of Java Indigo for Seed.

Introduction. In general, in Bihar, Java indigo is sown in October, after the rains have ceased, and it is now customary to grow it with a cold weather cover crop such as mustard or wheat. The indigo plants remain small during the cold weather and do not grow much in height till the temperature rises towards the end of February, after which period the cover crop ripens and is harvested. The indigo fields are not always free from weeds during the hot months of April and May, and this circumstance, in addition to the hard condition of the surface soil, often leads to a great loss of soil moisture and consequently to a backward condition of the plant at the time of the early rains in May. Indigo is able to survive the hot dry season in Bihar without irrigation solely on account of the nature of its root system. The tap root of young Java indigo in March is several feet in length and extends well down into the moist subsoil. But for this, the young plants,

which are then only a few inches high, would be rapidly destroyed by the high temperatures and by the dry west winds which sweep over the country at this period. Indigo is the only commonly cultivated crop in Bihar which grows in the hot weather. With the advent of moist east winds and the early rains in May, the plant grows rapidly and by the middle of July the first cut is taken. The crop is cut back completely and from the stumps new shoots are produced which form the second cut, which is taken as before towards the end of August. When seed is desired, this is produced from the third set of shoots formed in September. The seed ripens in February and March by which time the indigo fields are often very foul with weeds, leading to great trouble and expense in the preparation for subsequent crops.

Rainfall. The bulk of the rain in Bihar falls during the active growth period of the indigo crop, from the middle of June to the middle of September and often exceeds 20 inches in a month. This naturally leads to a constantly wet condition of the surface soil, even on well-drained land. With the progress of the monsoon, the level of the subsoil water rises considerably and lowlying areas are often under water. Indigo is killed outright by standing water but manages, for a time, to resist the continual wetness of the closely packed surface soil, the main characteristics of which in Bihar are the fineness of the soil particles and its power of retaining moisture. It is towards the end of the monsoon that the crop first begins to show signs of want of vigour and a distaste for its environment. After the first cutting, the new shoots grow slowly and are often unhealthy. The fresh growth is formed with great difficulty and frequently the new branches drop their leaves and wilt off. The second cut is often small in amount while the plants left for seed in many cases produce a small crop of very poor quality. From this unpromising material the new generation is raised and at the present time Java indigo cultivation in Bihar is in a thoroughly vicious circle. The poor seed yields a weak crop which, in turn, gives still more degenerated seed. To a greater or less extent this has been going on since 1909, when the dry cycle, during which this crop was introduced into Bihar, came to an end and the present cycle of rainy years commenced. During the period of low rainfall, Java indigo did well and gave two or three cuts of leaf and then a good seed crop.

The practice of growing seed from an old worn-out crop cannot be too strongly condemned. Under such circumstances degeneration is bound to occur as has been the case in Java indigo cultivation in Bihar. Good seed is essential for any crop and too much care cannot be taken in its growth.

On the older alluvium of the Doab of the United Provinces at Cawnpore, where the rainfall is less than in Bihar, the crop can be grown to perfection for seed under canal irrigation. There the soil is of a coarser texture and is of smaller water-holding capacity than that of Bihar. At the same time the level of the subsoil water during the monsoon is at a greater distance from the surface in the Doab than in Bihar.

Indigo 'Disease.' The unhealthy condition of Java indigo towards the end of the monsoon is regarded locally as a disease. The affected plants are characterized not only by a great reduction of leaf surface but also by a pronounced unhealthy appearance of the remaining leaves. The typical green colour of the foliage of healthy indigo is absent and the general tint is a yellowish-green slaty colour. All the external symptoms point unmistakably to root trouble which further examination confirms. The fall of the leaf at a time the plant should be growing vigorously to prepare for seed formation shows that something is interfering with the supply of food materials from the soil. There is no obvious stem disease. The soil is moist, so drought is excluded. The trouble must therefore be due to something amiss with the roots. The root system of this plant is very characteristic. There is a long tap root and a great development of long thick laterals, mainly concentrated in the first ten inches below the surface. Below this, the number of laterals on the tap root is small. The appearance of the large roots of affected plants is healthy and there are none of the symptoms of definite disease. There are however very few feeding rootlets to be found anywhere. The functional root system is extraordinarily limited and almost absent on the laterals near the surface. Little beyond the main root system is alive and the almost entire destruction of the finer roots is most striking. This at once explains the unhealthy appearance of the crop towards the end of the monsoon and the failure of the plants to ripen proper seed afterwards. The fall of the leaves and the wilting of whole branches represent efforts on the part of the plant to adapt itself to the gradual loss of its active root system.

Similar 'diseased' conditions. The unhealthy appearance of Java indigo at the end of the monsoon is by no means unique in Bihar. A similar state of things has for several years been observed by us in the Botanical area at Pusa in such crops as *patwa* (*Hibiscus cannabinus*, L.) and *sanai* (*Crotalaria juncea*, L.) *when sown at the beginning of the monsoon for seed purposes.* Several varieties of these two crops grow very well at first and begin to set seeds in the ordinary course. Frequently, however, an unhealthy condition is observed, the foliage loses its fresh appearance

and leaf fall begins, often followed by the sudden wilting of the whole plant. Examination of such plants in the early stages of the trouble again shows a great diminution of young roots and in the case of wilted plants the entire destruction of everything besides the main tap root. Indigo, *sann* and *patwa* are all plants which cannot put up with constantly moist soil conditions for the whole of the monsoon period. They are all intolerant to long-continued wetness of the soil and under such conditions drop their leaves and eventually wilt off, being quite unable to form good seed.

Remedial methods. In searching for some practical remedy for this trouble, two lines of attack suggested themselves. In the first place, improvements in surface drainage and aeration of the soil might be expected to prolong the life of the plant. Secondly, sowing the crop specially for seed towards the end of the monsoon so that the developing root system would follow the fall of the subsoil water, which takes place after the rains, was a second possibility of success in case improved drainage and cultivation failed to avert the trouble in the case of indigo grown in the ordinary way. It was decided to try both these methods simultaneously.

Drainage and cultivation. A beginning was made with these experiments in 1912 on a field of Java indigo which had been raised under a cover crop of wheat sown in October 1911. Further experiments were made on some small plots sown for seed early in June 1912 at the break of the rains. All the indigo was sown in plots surrounded by trenches and no serious water-logging was possible through water standing on the surface. Everything went well till the first cut after which the plant became unhealthy and gave a very poor second crop. The portion kept for seed was poor and a good deal died before the end of the year. Only a small quantity of poor seed was obtained. In all cases the plots were kept free from weeds and after the first cut the land between the plants was broken up with the *kodar* so as to let in a supply of air.

In 1912-13, these experiments were repeated, both on indigo sown under wheat as a cover crop and also on plants established on irrigation in April 1913. In the case of the indigo grown under wheat, the plants were in rows two feet apart so that the land could be opened up between the rows by a subsoil plough before the rains and other methods of cultivation could be tried. The scheme of the experiments can be understood from the following :—

1. Control plot. No cultivation beyond the lever harrowing given to all the plots after the removal of the cover crop of wheat in March.

2. Subsoiled between the rows on June 9th to a depth of one foot. Cultivated with Planet Junior horse hoe after each cut.

3. Cultivated between the rows with a Planet Junior horse hoe in April followed by subsoiling early in June. Cultivated by the Planet Junior horse hoe after each cutting.

4. Subsoiled between the rows early in June after which the rows were ridged. The ridging was repeated after each cut.

5. Java system. Subsoiled in May and trenches about six inches deep were cut between alternate rows, the earth being put on the beds. Subsequent cultivation consisted in keeping the drains cleaned out and putting the earth back on the beds. This ensured a large volume of aerated earth for root development during the rains.

Two cuttings of indigo were obtained. A good deal of wilt occurred after the first cut and the remaining plants were left for seed. They promise to give a fair crop only. The outturns of plots 1, 2, 3 and 4 were practically identical while there was an increase of roughly fifty per cent in the case of the plot cultivated on the Java system. The expense of this system however would be far too great for adoption in Bihar. The general result of these experiments showed that any ordinary system of subsoil or surface cultivation or both combined before the rains is not sufficient to prevent wilt or to ensure a really good seed crop.

In the second set of cultivation experiments, the plots were raised on irrigation in April 1913. In some, the seed was sown direct, in others, the crop was transplanted from a nursery. The plants were well-spaced both ways and the drainage and cultivation were as near perfection as could be attained under experiment station conditions. One half of the plants were pruned, the rest left for seed. The indigo grew to a great size and commenced to form seed. Leaf-fall and wilt however began towards the end of the rains and the condition of the plots at the present moment (January 5th, 1914) can only be described as poor.

The general result of the experiments on drainage and cultivation for the prevention of wilt and the formation of seed have, with the exception of the Java method, given negative results for two seasons. This has been the case on indigo sown in October with a cover crop and also with indigo grown from seed and transplanted at the break of the rains. The water-logging which takes place in the Bihar alluvium and which leads to the destruction of the young roots of the indigo cannot be prevented by

drainage and cultivation. The plant will not tolerate the constantly moist condition of the soil for the whole of the monsoon period. Like *sanai* and *patwa* long-continued wetness is fatal to Java indigo.

August Sowings. The experiments on sowing the crop for seed towards the end of the monsoon must now be considered. It has been shown that Java indigo will not tolerate more than two months or so of constantly moist soil conditions such as are experienced in an ordinary monsoon. It appeared likely therefore that sowings about the middle of August on high lands in good heart might escape wilt and might come into flower in October and November and carry a crop of well-grown healthy seed which could be gathered in February and March.

The first trials were made at Pusa in August 1912 on a very small scale. The plants escaped wilt and carried a fine crop of healthy seed. Side by side were the wilted plants raised from seed sown in June. The contrast between these two was most marked.

The second set of trials was made at Pusa and also on the Dholi estate during the last monsoon. The Pusa results will first be considered. Seeds were sown direct and seedlings were transplanted at the end of August both on poor, medium and on fertile soils. The crop was set out in lines, two feet apart, so as to admit of surface cultivation between the rows by means of small Planet Junior hand hoes so as to conserve the soil moisture after the rains. In some cases, the plots were green-manured with *sanai* before sowing the indigo, but in one instance this interfered with the germination of the seeds. As in 1912, the results have been exceedingly favourable and fine healthy plants, free from wilt and covered with good pods, have been obtained. Some mistakes were made in sowing which will be remedied in future years. The plants were not always so thick in the lines as they should have been. Further, sowing a fortnight earlier, about August 15th, would have been better. The fields in which it is desired to grow seed should be high-lying, well-drained and in good heart, somewhat like good tobacco land. This is essential so as to promote rapid growth and to raise large plants by the end of October so that the maximum seed crop can be carried. If sown in poor land a large seed crop is not likely to be obtained. It is also essential that the plants should be in lines about two feet apart so as to give enough space for branching and for the proper setting of the seeds. The reason for this spacing depends on the method of pollination in Java indigo—a subject which will be referred to in the next section (p. 13).

The experiment of August sowing for seed on the Dholi estate also promises well. The area sown was 12 bighas and the seed was put in on August 1st. The plants grew with great vigour and proved that indigo sown at this period escapes the so-called disease. Mr. Danby considers the crop is too thick for seed and had the field been sown in lines, two feet apart, a far greater yield of seed would have been obtained. In this opinion we concur.

It is very probable that the crop grown specially for seed will yield good cuts of leaf the following monsoon. This is being tried now and the results will be published later. Possibly some pruning may be necessary after the seed has been collected, but this is a matter for future experiment.

Conclusions. The Pusa experiments on the growth of Java indigo for seed point to very definite conclusions. In wet years like the present, a crop of really good seed is, as a rule, impossible after cutting the indigo for leaf. In future, leaf growing and seed growing should be regarded as separate things. For seed, Java indigo should be sown about the middle of August on high-lying, well-drained, fertile lands. The seed should be sown in lines, about two feet apart, so as to promote branching and ensure abundant pollination. At first, cultivation and crust breaking should be carried out with the lever harrow but when the plants increase in size interculture and weeding should be done by means of the Planet Junior hand hoe. Grown in this way, indigo escapes the so-called disease and large crops of good well-grown seed can be obtained.

Cold weather cleaning crops. Closely connected with the growth of Java indigo for seed is the question of *rabi* cleaning crops in the general economy of the indigo estates. In Bihar, there are several troublesome cold weather weeds which, if unchecked, rapidly multiply and lead to great loss of fertility. This is particularly the case on good lands when put down to cereals year after year as in the case of the continuous wheat plots at Pusa. Weeds like *butwa* (*Chenopodium*) give great trouble. One of the best methods we have found in destroying these annual cold weather weeds is to grow a crop of *rahar* about every fourth or fifth year and to tumney the crop during November or December. This tumney, combined with the effect of the thick canopy of *rahar* leaves, cleans the land very efficiently. Tobacco is another good cleaning crop. To these two might be added Java indigo sown in lines in August for seed. By running Planet Junior hand cultivators down the lines after the *hathia* or later rains the

weeds can be killed off and the land kept clean. The present method of growing Java indigo by leaving the old crop for seed is the reverse of a cleaning crop. During the cold weather, weeds accumulate and old indigo fields in March are generally in a very foul state. The August sown crop, besides giving better seed, will act as a cleaning crop and so tend to improve the land for future use.

III. The Improvement in the Yield of Indigo.

Besides the supply of good seed there are two other directions in which the yield of indigo can be increased. In the first place, the crop can be improved by selection. In the second place, the present methods of growing indigo in Bihar are capable of considerable development. Attention has been paid to both these methods, and, in the following pages, they will be considered separately.

The Improvement of the plant itself.

Pollination. Indigo is a crop grown from seed. As is well known, the seeds are formed in pods each of which arises from a flower. For seed to set the flowers must be pollinated, that is to say, pollen must be transferred from the anther to the stigma. In the work of improving a crop, an accurate knowledge of the way in which pollination takes place is the first condition of progress. This is necessary, not only in the work of selection or breeding an improved crop but also in devising the best system of seed-growing and of seed distribution.

In some crops, self-pollination is the rule. In such cases pollen falls on the stigma of the same flower and self-pollination ensues leading to the formation of seed. Wheat is an example of a crop in which self-pollination is the rule. Once an improved wheat, which breeds true, is found either by selection or by breeding, all that is necessary is to multiply the seed from one plant and to arrange a suitable method of seed distribution.

In other crops like tobacco and cotton, a considerable proportion of cross-pollination takes place. Here both in selection and in breeding precautions are necessary to prevent crossing. This is essential in all the work connected with obtaining a new variety and also in seed-growing and in seed-distribution. If these precautions are not taken, the improved varieties cross with others and the improvement is lost in a very short time.

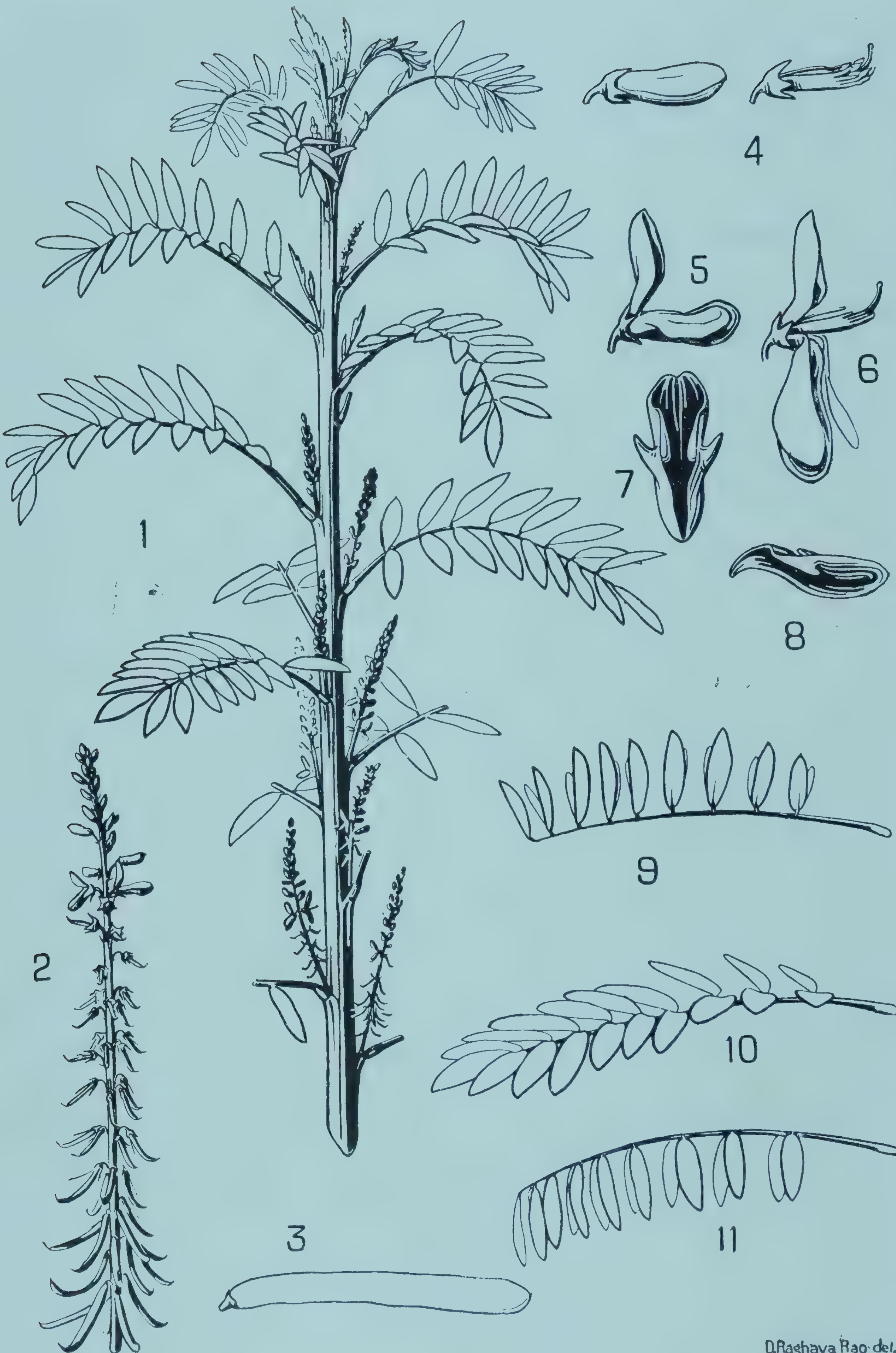
In a third class of crops, cross-pollination is the rule and self-fertilization the exception. Maize and some of the oil-seeds are examples of such crops.

Here the methods of selection that can be applied to obtain an improved plant are quite different from those which are used in crops like wheat and tobacco. Java indigo belongs to this class.

The method of pollination in the case of Java indigo has been studied by Parnell at Sirsiah, and in the last report of that station he described the result of his investigations as follows :—

" Examination of the flower of *I. arrecta* reveals a mechanism designed to ensure extensive cross-fertilization. The style projects through the ring of anthers and carries the stigma into the closed apex of the keel where it is protected from contact with the pollen liberated lower down in the keel by the bursting of the anthers shortly before the flower opens. By carefully exposing the stigma of an unsprung flower one can see that it remains free from its own pollen in almost every instance. If the spring mechanism is not released, the flower remains in this condition for several days when it begins to fade and the pollen may gain access to the stigma and produce self-fertilization. This latter event however occurs rarely; this may be due partly to the fact that the pollen does not always reach the stigma and partly to the fact that the pollen of an old flower possesses considerably less germination power than when it is fresh, a fact readily demonstrated by germination tests done in an agar solution containing 15 per cent cane-sugar.

Normal fertilization appears to be brought about through the agency of insect visitors. In the young open flower, a state of tension exists between the ovary and the keel. The latter exerts a strong downward pressure on the ovary and is kept in position by means of a fold of its free edge on each side, the two folds coming together for a short space over the ovary about the middle of its length. Two projecting spurs of the keel, one on each side level with the folds, support the wings as a level platform over the keel. When an insect alights on this platform the spurs are depressed, thereby separating the folds and releasing the ovary. The wings and keel spring down, owing to a sudden bending at their base, till they are about at right angles to the ovary which has jerked suddenly upwards. The stigma comes into immediate contact with the under side of the insect which is also covered with a cloud of pollen; in this way the stigma receives a mixture of pollen from the flowers already visited by the insect. This operation may be observed very readily in the field, being effected most commonly by *Aris florea* and *Halicius gutturosus*, two common Indian bees, both of which visit flowering indigo plants in large numbers."



JAVA INDIGO.

During the past two years we have examined the flowers of Java indigo in detail and our observations confirm and extend those of Parnell. The details relating to the flowers and the method of pollination can be seen in Plate I.[1] There is no doubt that pollination by means of bees is the rule in this crop and that in the absence of these insects little or no setting takes place. To prove this a number of large healthy indigo plants, which had been grown from seed sown at the end of August, were covered with frames over which mosquito netting had been stretched. The plants were put under the frames before any flowers had opened and the bases of the frames were sunk a few inches in the earth to ensure the complete exclusion of insect visitors. In all cases practically no pods formed, the flowers remaining open for a few days and then drying up. The covered plants grew, if anything, better than those outside. The ordinary uncovered plants set seed in abundance and the contrast in this respect between the covered and uncovered plants was most striking. In each of the covered plants one branch was allowed to grow outside the net, an arrangement having been made for this purpose which excluded insects. The branch growing out into the free air in all cases set seed, thereby proving that the failure to set seed on the part of the covered plants was not due to any weakness of the plant itself but solely to the exclusion of insects.

In order to form some idea of the amount of natural cross-fertilization which takes place between the various types of Java indigo, which constitute the crop as cultivated in Bihar, the seed of a large number of plants of the 1913 crop was sown singly at the end of August last and the resulting cultures examined. None of the plants bred true but gave rise to mixed cultures, thereby confirming the occurrence of extensive natural crossing in this crop. Variation due to crossing took place in many obvious characters, such as colour of the stem (whether green, intermediate or red), time of flowering, habit of growth, size of leaves, amount of total leaf surface and rapidity of growth.

The fact that the flowers of Java indigo only set seed when visited by bees is a detail of importance from the point of view of seed production. For bees to do their work, the plants must be suitably spaced to allow of

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[1] *Description of Plate I.* 1, a flowering branch of Java indigo. 2, a complete inflorescence. 3, a ripe pod. 4, a flower bud showing the relative position of the anthers and stigma just as the pollen is liberated. 5, a fully opened flower. 6, a sprung flower. 7, the keel seen from above showing the projecting spurs and folds. 8, half the keel seen sideways showing the fold which keeps the young pod in place. 9, the position of the leaflets at midday. 10, a leaf in early morning. 11, the position of the leaflets at dusk.

branching and for a full supply of air and light to the flowers. This is impossible in the case of indigo grown close together in the usual Bihar custom. Such closely grown plants do not branch and only form seed at the tips of the branches where they get enough air and light to ensure visits by bees. In the Pusa experiments, the plants were sown in lines, two feet apart, and this was found to be a suitable distance for seed production in the case of a crop grown in rich land.

Selection. In considering the question of selection in Java indigo the following circumstances have to be kept in view :—

1. Cross-pollination by bees is the rule in this crop and little or no setting takes place when the flowers are covered.
2. Any plant selected on account of the high indican-content of the leaf is not likely to breed true but to give rise to all kinds of offspring as regards indican-content.
3. The crop, as ordinarily grown, consists of several distinct types of plant, some of which grow much more rapidly and robustly and carry far more leaves than the bulk of the crop.

These circumstances do not permit of the application of ordinary single plant selection methods to Java indigo.[1] To obtain an improved plant other methods must be applied. Advantage will have to be taken of those individuals in the mixed crop which grow rapidly and strongly and which by their habit of growth and amount of leaf-surface are likely to give the highest yields of leaf. These will have to be grown separately away from other indigo and a process of roguing carried out before flowering time so that all undesirable types are weeded out and not allowed to cross with the rest. In a short time a type of plant will be isolated which will give larger crops than the average, and it is exceedingly likely that the yield of finished indigo will also be increased.

Resistance to wilt will also have to be considered in obtaining an improved indigo. The constituents of the ordinary mixed crop vary

[1] In considering the improvement of indigo by ordinary methods it must be realized that this implies hand-pollination throughout all stages of the pure-line selection and breeding experiments, an almost impossible task when it is remembered that each flower sets so few seeds. The task of improving a character so difficult to estimate and so elusive as indican-content would not be worth the great labour and expense involved. Moreover, if self-sterility occurs, as Parnell states, the success of any such experiments would be exceedingly doubtful. Lastly, even if such an improved type could be produced its maintenance and the distribution of seed to estates would offer insuperable difficulties.

greatly in their resistance to wilt. By a second selection for wilt resistance among the survivors of an improved leaf-producing indigo, a disease-resisting strain could be isolated which would give still better results. Work on these lines is bound to result in a better plant than the one now grown in Bihar.

That the method of improvement here advocated is likely to yield the best results is supported by the experience obtained with the various varieties of Sumatrana indigo. As is well known, there are several types of this indigo which do not vary much in indican-content. The yield of the Delhi-Cawnpore type however is much greater than the rest. This is due to its robust habit of growth and to the fact that the total amount of leaf produced is much greater than that of any of the other varieties.

Improvements in the growing of indigo.

A perusal of the reports on indigo investigations in Bihar shows that, with the exception of the work done at Pemberandah, very little attention has been paid to methods of cultivation. It has been tacitly assumed that the practices in vogue are more or less perfect and that any line of advance in improving the crop must necessarily begin in the laboratory. Our experience at Pusa has been the direct opposite and we have found that a considerable degree of improvement is easily possible. In the following paragraphs a brief account is given of the experiments in progress at Pusa on the growth of indigo and of some of the improvements in the management of this crop which we have found can easily be applied under estate conditions.

Harrowing indigo in the hot weather. In one respect the present methods in use in Bihar in the cultivation of Java indigo are exceedingly defective. After the removal of the cover crop, the indigo fields are left to bake in the sun and the extremely tedious and expensive system of hand-weeding is largely relied on to weed the crop. A study of the indigo plant at this period indicates that two things—mulching and weeding—are necessary immediately the cover crop is removed. A deep mulch of fine dry soil must be formed on the surface to prevent baking by the sun and to conserve the moisture in the subsoil and so enable the indigo to grow during the hot weather. The best time to prepare the mulch is immediately the cover crop is removed. The best method is by the use of lever harrows which should be set to work in the fields the same day as the cover crop is removed. For a short time after the cover crop is reaped the

surface soil is moist enough to enable a good thick mulch of fine soil to be worked up by the harrows with the minimum expenditure of bullock power. A few days later the soil becomes baked and the labour and difficulty of working up a suitable mulch are increased. Besides conserving the moisture, the mulch promotes aeration of the roots of the indigo, a matter of great importance to the well-being of the crop. The effect of this harrowing on the indigo is most marked and the crop begins to throw out new leaves at once and to grow in size.

There is another advantage in harrowing the young indigo. As is well known, Java indigo is a deep-rooted plant and so is not easily uprooted. On the other hand, many of the weeds, which are found in the fields at this period, are shallow-rooted and in consequence easily removed. By suitably adjusting the tines of the lever harrow it can be used as a weeder as well as a mulch producer.

These lever harrows have been tried extensively on the Dholi estate for two seasons and Mr. Danby reports as follows on the trials (Letter, dated January 3rd, 1914) :—

"I meant to have written before about the lever harrows. I had six of these lever harrows in use last year and I have ordered six more from Messrs. Massey Harris.

"I harrowed practically the whole of my Java crop in February and March last after cutting the cover crops—wheat and *sursoo*. The crop was greatly improved by the harrowing, besides which the wheat stubble and weeds were to a large extent removed. I estimate that the amount saved in weeding alone in the one year was more than the price of the harrows.

"I put these harrows through some of my wheat and oat crops after the rain we had in November 1912 and the improvement in the crops which had been harrowed was very marked when they came into ear."

We have no hesitation in recommending these lever-harrows for extended use on the indigo estates in Bihar. They were first introduced into India for the *rabi* crop of 1911 and were shown at the Tirhut Agricultural Exhibition held at Pusa in January 1912. Wherever they have been tried since, the verdict has been uniformly favourable. At Quetta by their use the yield of dry crop wheat has been raised from five to over nineteen maunds to the acre on a plot three acres in area. The yield on zamindars' land during the same year was about five maunds to the acre. They can be

used in Bihar for Java indigo in the hot weather, and also for breaking *papri* on young *kharif* crops, and also for *rabi* crops like oats and wheat. They will take the place of the rakes used on indigo factories.

The best pattern lever harrow we have tried at Pusa is the one made by the Massey Harris Company, Toronto, Canada, at a cost of 12·90 dollars. This is the smallest size of two sections and is 9 feet 8 inches wide. There is one difficulty however in importing these implements. The wooden parts of small consignments of agricultural machines usually disappear during the unloading process at Calcutta. This would be avoided by pooling the orders sent by indigo factories and giving instructions to the shippers to send out the wooden parts in suitable crates. A large crate would not be so likely to disappear as loose wooden bars which are suitable for mending bullock carts and other domestic purposes.

The Reduction of Wilt. A good deal of consideration has been given at Pusa to the discovery of some practicable method of reducing the amount of wilt among Java indigo when grown for leaf. Very promising results were obtained during 1913. As is well known, the universal method of growing Java indigo in Bihar is to sow it either broadcast or by drills in lines close together. The result, in both cases, is a dense crop of unbranched plants among which leaf-fall rapidly takes place due to the crowding of the plants, thus leading to a loss of indigo. Further, interculture to keep down weeds is impossible after the first cut. When the crop is reaped, the indigo is cut down completely and the plant has to produce new shoots during the monsoon at a time when its roots are in very moist soil. Few plants will survive uninjured such treatment during the month of July. When an indigo plant is suddenly cut down, the passage of water and food materials from the roots goes on for a time and the stumps bleed. There are no leaves to carry on the transpiration current and the result is that the normal physiological processes in the plant are greatly upset. It is not surprising therefore that the new growth is formed so slowly and that it is often unhealthy. Many plants, such as peaches and flowering creepers like *Ipomœa,* usually die outright when cut down to the ground during the rains and hardly ever recover.

It was decided in 1913 to try the effect of pruning the crop in July at the time of the first cut and to compare the behaviour of plants treated in this way with those cut down completely. To enable the crop to branch freely the indigo was sown in lines, two feet apart, and weeds were kept down so as not to interfere with free-branching from the lowest part of the

stem. One half of the plot was cut down in the ordinary way, the rest pruned so that one branch was left at cutting time. The results of the first and second cut are given in the following :—

	Plants pruned.		Plants cut down completely.	
	m.	s.	m.	s.
First cut . . .	15	11	22	39
Second cut . . .	23	37	6	19
TOTAL .	39	8	29	18

It will be seen that the method of pruning at the first cutting and leaving a branch to carry on the growth has resulted, as was expected, in a material increase in the total crop. There is of course some loss in the pruned plot at the first cut due to the branches left. This is however more than made up for in the greatly increased second cut on the pruned plot. Not only was the total amount of plant increased by pruning, but there was also a great reduction in wilt. Moreover, the pruned plants formed new shoots more quickly than those which were cut back to the ground.

These experiments indicate that a considerable increase of indigo per bigha can be obtained by pruning the crop at the first cut so as to leave a branch to carry on the growth. Pruning can only be done if the plants are grown in lines so as to allow of branching from the base. The raising of the crop in lines also facilitates surface interculture after the first cutting so as to keep down weeds. Growth in lines will also tend to prevent the fall of leaf which takes place in indigo grown too thickly and which must lead to great losses of produce. Extended experiments on this point are necessary so as to work out a practicable method of growing the plant in lines and of obtaining the maximum total crop. The distance apart of the rows and the best methods of pruning can only be settled by extended trials on the various indigo soils. Pruning the crop, as ordinarily grown, is not practicable as the plants are too close together and do not branch near the ground.

Removal of the old Crop. All the experiments at Pusa show that in years of ordinary rainfall, the plant ceases to be productive about the time of the second cut. At this stage the young roots die, leaf-fall begins

and wilting soon takes place. The crop has finished its work and nothing is to be gained by keeping it for seed or for a third cut. At the second cutting the plants should be cut down to the ground and the stumps dug out so that the fields can be got ready for a *rabi* crop. In this way weeds are kept down and the lands will not deteriorate as they do now when left for seed. As explained above (p. 10) seed-growing and leaf-growing should be regarded as separate things and the practice of leaving old indigo for seed should be given up.

Cover Crops. One of the needs of the indigo industry is a valuable cover crop for the Java plant which will do well on the lands usually put down to this crop. Some attention has been paid to finding a variety of wheat which could be grown with indigo. High yielding wheats are unsuitable for this purpose as their foliage is too thick and they choke the young indigo plants and allow of too little light and air reaching them. What is required is a rapidly maturing wheat with a strong straw, which will grow on light land which does not lodge and which has only a small amount of foliage. The selection, known as Pusa 4, has been grown successfully with Java indigo, and seed of this variety is now on the market. This wheat must be sown rather thickly at the rate of about 80 lbs. to the acre if dropped in the furrow behind the plough. Seed of the variety can be obtained from the Dholi estate.

IV. Summary.

The conclusions reached in the present paper can be summed up as follows :—

1. The so-called 'disease' of Java indigo, which ends in the wilting of the plant, is due to long-continued wetness of the soil. This wetness leads to the destruction of the young feeding roots which is followed by leaf-fall and then by the more or less complete wilting of the plant.

2. For a time this wilting can be checked if the plants are pruned at the first cut so as to leave a branch.

3. Pruning instead of complete cutting back at the first cut leads to an increase in the total crop.

4. After the second cut in an ordinary monsoon indigo ceases to be profitable and should be dug up to make room for *rabi* crops.

5. The growth of indigo for leaf and for seed should be regarded as separate things and seed should not be raised from the old plants which have been cut for leaf.

6. The best method of obtaining good seed of Java indigo is to sow the crop in lines about 24 inches apart in the middle of August on high-lying, well-drained fields which are in good heart. After gathering the seed the crop can probably be grown on for leaf during the next monsoon.

7. Java indigo is greatly improved and a good many weeds are removed if it is harrowed as soon as possible after the removal of the cover crop.

8. When wheat is grown as a cover crop an early maturing variety with little foliage and stout straw gives the best results.

It now remains to outline briefly future work on indigo in Bihar. The present paper is only a beginning, but enough has been written to show that this crop will well repay investigation. Investigation should not be confined to the Java plant, but the Sumatrana species requires attention.

The requirements of both kinds of indigo from the physiological standpoint should be studied. It is not known with precision what part indican plays in the general economy of the plant and how the various growth factors influence its production. Work on this point would be certain to lead to practical results.

Much remains to be done on the agricultural side and in the perfection of improved method of growing the crop. Speaking generally the standard of agriculture in India is low and Bihar is no exception to the rule.

In the past, practically nothing has been done to improve Java and Sumatrana indigo by selection and to work out a proper system of seed distribution suited to Bihar conditions. The prospects of success in improving Java indigo by eliminating undesirable types are most promising. So far no work has been done on Sumatrana indigo from the point of view of improving the variety.

A suitable system of seed distribution in the case of both Java and Sumatrana remains to be built up. There seems no reason why, if sown in August, Sumatrana could not be grown for seed in Bihar and the best varieties should be maintained for this purpose.

DRAINAGE AND THE PREVENTION OF LOSS OF SOIL BY RAIN WASH.

Our experience in growing crops in the Botanical area at Pusa during last eight years has led to the conclusion that some system of surface drainage combined with the prevention of loss of soil by rain wash is the first condition in improving the crop-producing power of the soils of Bihar. Without drainage, water-logging is bound to occur, while the annual loss of fine soil that is taking place every year on the large *zerats* near the indigo factories can easily be appreciated when the fields are visited in the monsoon during heavy falls of rain.

The subject of drainage and soil denudation was referred to in the previous addresses to the Bihar Planters' Association published in *Pusa Bulletin* No. 33. This paper has been distributed to all members of the Association. The losses of crop due to water-logging were shown to be very great and in the experiments cited were over sixteen bushels of wheat to the acre in a single season. This loss of crop was shown to be due to the destruction of available nitrogen in the soil by water-logging, probably caused by denitrification. It was also pointed out that green-manuring with *sanai* only gave uniformly good results on high lands which had been drained and that water-logging after the *sanai* crop was ploughed in often reversed the effect of the green dressing and led to a smaller crop than that produced by unmanured land. A method of surface drainage by means of trenches and grass borders was described in detail and great stress was laid on the importance of splitting up the rainfall into units and allowing each plot to deal with its own rain only. Lastly, the importance of this system of drainage in preventing the loss of fine soil was emphasized in the following words :—

"The experiments on surface-drainage at Pusa have demonstrated a further point in the improvement of the high lands in Bihar to which I should like to direct your attention. This is the prevention of surface wash or the removal of the fine particles of soil by the rain-water which runs off these fields towards the rice lands. Whenever the slope is great enough for water to move, this wash is going on and is one of the factors responsible for the destruction of the fertility of the high lands. On the plots at Pusa the grass borders tend to prevent the loss of the fine particles of the soil by surface-wash. Consequently, the lower ends of the plots are getting higher

every year and the whole surface tends to become more and more level. The increase in height of the lower areas represents the amount of soil that would have been lost by rain-wash had not this been checked by the grass borders. Further, the lower ends of the plots which have received the surface-soil from the upper areas are yearly increasing in fertility. The fine soil is now being held up and this increases the water-holding capacity and fertility of the soil very markedly. If these effects can be obtained in three years in plots one acre or less in area with slopes imperceptible to the eye, it requires no great imagination to realize what must be taking place on the large fields surrounding indigo factories. The annual loss of fine soil must be enormous and its prevention by the simple method of drainage advocated last year will repay the cost and trouble involved. Further, the fertility of the land will be improved, water-logging will be checked and the introduction of green-manuring with *sanai* and other crops into the general agricultural practice of Bihar will be accelerated."

Since this Bulletin was written the system of surface-drainage adopted in the Botanical area at Pusa has been taken up on two estates—Doulutpur and Dholi. At Doulutpur, the *zerats* have been divided into plots one bigha in area, separated by drainage trenches, the small trenches communicating with larger ones which act as small drainage canals and carry off the excess water. On this estate the system is being extended at the rate of about one hundred bighas a year and this centre will serve as a good object lesson for other estates where it is desired to rent the fields to small cultivators. The bigha plots ensure good drainage and also allow of successful green-manuring with *sanai* for crops like tobacco. Further, the bigha plots enable accurate records of the crop-producing power of the land to be kept and also save much time in measuring the land and also in allotting it to the selected tenants.

On the Dholi estate, the plots are larger so as to admit of the use of reapers and other labour-saving devices in the cultivation of wheat for seed purposes. This system of plots, each about five bighas in area, is suitable for estates which either cultivate their *zerats* or let out the land to well-to-do *raiyats* who require areas of more than one bigha. Mr. Danby, in a letter dated January 3rd, 1914, gives his opinion on this system of drainage as follows :—

" During the past year I have applied the system of surface-drainage to some 40 bighas, and I intend to extend it to the whole of my factory *zerats* here and at the outworks. The lands which I drained in this way this year

were formerly, in a wet year, more or less water-logged the whole of the rains owing to the water from the higher lands draining into them. This year I was able to cultivate and keep them clean all through the rains, and even after the late rains which we had this year I was able to sow wheat in them before the end of October."

One great advantage of a system of drainage in the heavier lowlying lands in Bihar, referred to in the above letter, should be emphasized. This is the ease with which these lands can be kept free from weeds during the rains and put down to *rabi* crops in good time. As is well known, it is impossible in Bihar to keep ordinary undrained lowlying fields clean by surface cultivation alone during a heavy monsoon on account of the fact that the soil is for long periods of time too wet for any form of cultivation. Further, at sowing time, such lands are not dry enough to be ploughed till late when the difficulty of reducing them to a good tilth is very great. These circumstances greatly lower the value of lowlying lands. When, however, these lands are drained and have to deal with their own rainfall only a great change takes place. Cultivation is easily possible during the rains while they can be prepared with comparative ease in good time for sowing *rabi* crops. Once drained these heavy lands give large crops year after year without manure. It is no exaggeration to say that the value of lowlying, heavy lands in Bihar, which are capable of drainage, can be doubled by the system of surface drainage we have advocated.

The value of this method of drainage in preventing the loss of fine soil by surface wash is now very evident in the Botanical area at Pusa. The process of natural terracing, which gradually takes place, is now well marked. The lower ends of the plots are now considerably raised, in some cases as much as 6·5 inches in four years. This raising of the lowest ends of the plots represents the deposition of silt by rain wash carried from the upper areas of the fields. What was once an even surface is now becoming a series of terraces. Had the fields not been cut up into sections much of the deposited silt would have been carried away by surface wash to the rice lands below, and so lost. Several measurements of the rise in the levels of the lower sides of the Pusa plots since 1909 have been made. In plot I of the Northern Trial Ground, which slopes from south to north and is 94 feet wide, the rise on the north side amounts to 6·5 inches. Similarly in plot 2 of the Pentagonal Field, which slopes from north to south and which is 194 feet wide, the south side has been raised 4·5 inches in the last four years.

In order to carry out this system of drainage in practice a drainage map is essential. This can best be obtained by following the system originally devised by Sir Edward Buck in 1870 when Settlement Officer in the Farrukhabad District. This consists in marking on an ordinary map the directions in which rain water runs off the land. This enables the drainage lines to be determined far more easily and cheaply than by any system of taking levels.

Conclusions. The first condition of progress in any scheme of improvement in the crop-producing power of the soils of Bihar is a system of surface drainage by which each field deals with its own rainfall only. In this way all lands are benefited. On high lands, green-manuring with *sanai* **can be carried out with safety while the cultivation and crop-producing power of lower lands are materially increased. The Pusa system of drainage also prevents the denudation of the soil by rain wash and the loss of fine particles which are now carried away every year from the high to the lowlying areas. The cost of this system is small and is well within the means of any indigo estate or** *zamindar*.

GREEN-MANURING WITH *SANAI* IN BIHAR.

A supply of organic matter in some form is essential to the maintenance of the fertility of the high lands in Bihar. If the humus in the soil of these lands is allowed to run too low, the fertility falls off and the fields are unable to retain enough moisture to ripen off a *rabi* crop. This is the reason why the high lands respond so markedly to applications of indigo *seeth*, to farm-yard manure and to various oil-cakes. To a less extent a *rahar* crop, which adds by the fall of its leaves and flowers a good deal of organic matter to the soil, also improves the fertility of these lands. With the diminution in the cultivation of indigo the supply of *seeth* is now insufficient for the higher lands. Some *seeth* substitute must therefore be looked for, and our experience at Pusa proves that a green crop of *sanai* ploughed in during the monsoon is a valuable substitute for indigo *seeth*.

The earlier results obtained with *sanai* in the Botanical area at Pusa have been published in the *Agricultural Journal of India* (Vol. VII, Part I, 1912). This work is also referred to in *Pusa Bulletin* No. 33. In the case of tobacco, the experiments showed that two conditions are essential for success in ploughing in *sanai* as a green manure—drainage and time. Green-manuring should only be attempted on light, high-lying lands which are *well-drained* so that each field has to deal with its own rainfall only. Soakage from other areas after the green crop is put in leads to great loss of fertility and often to a yield below that of unmanured land. *The time of ploughing in is everything*. In 1910, we recommended July 15th as the best date for turning under the *sanai* for the succeeding tobacco crop. Subsequent experience has confirmed this. Tobacco is usually transplanted about the middle of September, so that there is a period of two months for the green crop to decay and for a portion of its organic matter to be transformed into a form which the tobacco crop can take up. We found in 1909 and again in 1910 that if, for any reason, the succeeding crop after *sanai* is planted late and the period of two months became three to three and a half months, then the value of the green crop is lost and the available nitrogen in the soil disappeared.

During the past year we have obtained further confirmation of our original recommendations. An even plot of light, high-lying, drained land in poor condition was green-manured with *sanai* for tobacco and divided into three plots. In the first plot the *sanai* was ploughed in on July 15th, in the second on August 7th, and in the third on August

28th. Cigarette tobacco (Type 28) was planted into all these plots on September 25th and 26th, the plants being set out 30 inches apart each way. The dates of sowing and ploughing in the *sanai* were as follows:—

	Sanai sown.	*Ploughed in.*
Plot 1	May 18th.	July 15th.
Plot 2	June 15th.	August 7th.
Plot 3	June 30th.	August 28th.

Sown in this way the amount of green manure ploughed in in all the plots was practically the same.

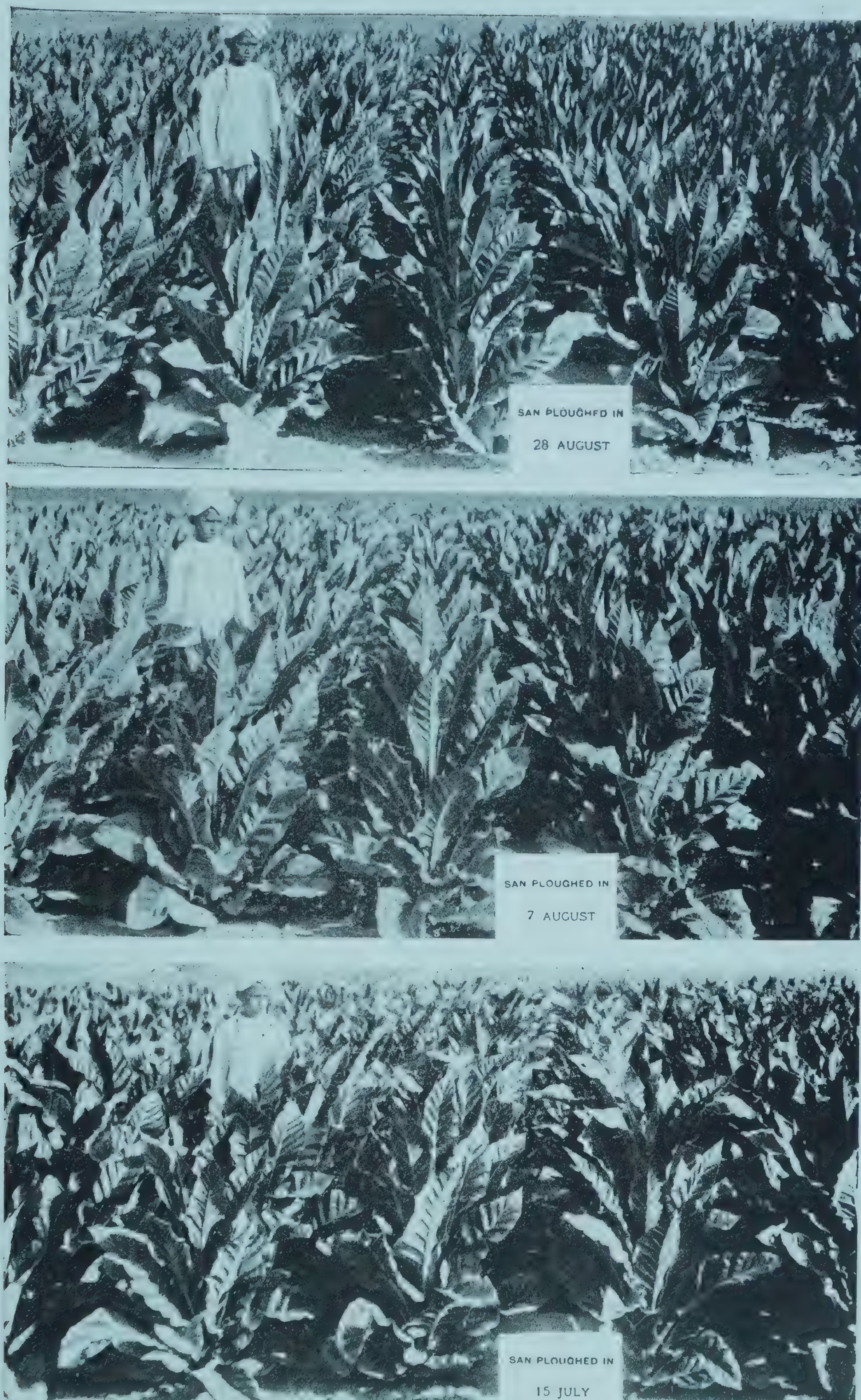
The results of the experiment were very striking. The tobacco in plot 1 grew very rapidly from the beginning and has given the maximum crop that can be grown for cigarettes. Plot 2 is not so good while plot 3 is poor. The results are shown in Plate II. In all three cases the photographs were taken at the same distance from the camera.

These experiments again emphasize *the importance of time* in ploughing in the green crop. Any period less than two months is too short for the green manure to decay. We have already shown that after two months there is a loss of fertility following green-manuring. *Sanai* gives the best results when put in about two months before the next crop. It is of course a counsel of perfection to say that all *sanai* must be put in on a certain day. This is naturally impracticable under estate conditions. There is of course some latitude, and it would be a good rule to lay down that *sanai* for tobacco should be put in between July 7th and July 21st. Any crop not put in on July 21st should be cut then and left on the ground. Our experiments this year showed that *sanai* decays faster, if cut and allowed to wither a few days on the moist soil before being ploughed in, than if put under green.[1]

Conclusions. The experiments with *sanai* as a green manure for tobacco in the Botanical area at Pusa have led to very definite conclusions. Drainage is essential for success with green manure on the high lands. The

[1] Tobacco is a very suitable crop for experiments with green manures. In the first place, it is an excellent soil-analyst and gives most accurate indications of the amount of available nitrogen in the soil. In the second place, it can take up large quantities of available nitrogen to advantage as it is grown for leaf and not for seed. In crops like wheat, on the other hand, a large amount of available nitrogen leads to rank growth which is then not only liable to lodge but also more liable to rust attacks.

PLATE II.



TOBACCO GREEN-MANURED WITH *SANAI.*

sanai should be sown on the early rains in May and ploughed in as near July 15th as possible. Where large areas have to be dealt with the period from July 7th to July 21st would be suitable. Any crop left on July 21st should be cut at once, left on the surface and ploughed in as soon as possible. To get the maximum benefit of the green crop the interval between the ploughing in of the *sanai* and the transplanting of the tobacco should be eight weeks. A longer or a shorter time leads to loss.

PUSA,
January 17th, 1914.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 52 1915

Agricultural Research Institute, Pusa

SOIL VENTILATION

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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CONTENTS.

SOIL VENTILATION.

I. INTRODUCTION.

THE need of a plentiful supply of air for all growing parts of plants is well known. All living plant cells respire just as animals do, and, in the process, use up oxygen and produce carbon dioxide as a waste product. Air is therefore necessary for that part of the plant, the root system, which is below ground. This fact is well known, but the importance of continuous gaseous interchange between the soil and the atmosphere during the growth of a crop is not always sufficiently recognised. This is particularly the case in a country like India, where water is so often all important and a frequent limiting factor in crop production. The necessity for irrigation, the attention paid to dry farming methods and to water conservation, all tend to concentrate the attention of the investigator on questions relating to water and, at the same time, to obscure the importance of the air supply of the roots.

In the alluvial soils of the Indo-Gangetic plain there are several circumstances which tend to make gaseous exchange between the soil and the air difficult. The particles are for the most part fine and do not differ much in size. Natural aeration is not promoted by this uniformity and fineness in soil texture, while on drying, these soils do not crack to anything like the same extent as the black soils of Peninsular India. In some places, such as Pusa, the alluvium contracts on wetting, a circumstance which adds greatly to the difficulties of natural aeration. In the soils of the plains, ventilation is further interfered with by heavy rains which compact the surface, by surface flooding during irrigation and sometimes by inundation from rivers.

Some examples of damage to crops, attributable to want of air in the soil, are described in the present paper. These effects are most marked and in general simulate the results obtained with plants when the supply of nitrogen is deficient. In certain cases, the manifestations are still more pronounced and are often regarded as definite diseases. To this latter class many cases of wilt belong. Much of the want of success in crop-production in some parts of India is due to deficient soil aeration, and this is particularly the case in North Bihar, where want of air causes much more damage than want of water. The improvement of

agriculture in this tract, and probably also in other parts of the alluvium, will turn on successful methods of supplying air to the soil without at the same time unduly reducing the moisture. The aim must be to regulate the balance between air and water in the soil by methods within the means of the best cultivators.

A clear presentation of the relations between the air supply in the soil and root development is not often to be found in the literature. A great deal of emphasis is laid on the functions of the roots and on the part played by the root hairs in absorbing water and food materials. The needs of the active cells of the root itself are generally ignored. There is, however, one well marked exception. In Sorauer's *Popular Treatise on the Physiology of Plants*, occurs an excellent account of the needs of the root, in relation to practice, in which great stress is laid on the necessity of constant aeration, and of continuous gaseous interchange between the atmosphere and the soil. During growth, the oxygen in the soil is not only drawn upon by the protoplasm of the root hairs and of the other active cells of the root, but, at the same time, the proportion of carbon dioxide is greatly increased. This gas is given out by the growing cells and is also produced by the decay of organic matter. Many of the soil bacteria also need free oxygen and besides increase the amount of carbon dioxide. Unless copious ventilation takes place, the supply of oxygen will be exhausted and, at the same time, the soil air and water may become charged with carbon dioxide to such an extent that a poisonous atmosphere for the roots is produced. Growth will stop for two reasons. In the first place, there will be no air for the working cells of the root and they will die of asphyxiation. In the second place, there will be direct inhibition due to the presence of large quantities of carbon dioxide which Sorauer[1] states is a poison for roots.

The direct influence of aeration on the development of the root system has recently been investigated by Hall, Brenchley and Underwood.[2] These investigators found that in nutrient solutions, diffused over solid particles of various grades, far better root development and far better growth were obtained with silver sand and kaolin than with fine sand, silt or in water culture only. Want of aeration was suspected as the cause of the poor root development in the case of fine sand and silt and the correctness of this supposition was proved by direct water cultures of barley in solutions aerated once a day and aerated continuously. Continuous aeration gave much the better root development and also the better growth of leaves and stems.

[1] Sorauer, *Handbuch der Pflanzenkrankheiten*, Bd. 1, 1909, p. 99.

[2] *Jour. of Agr. Science*, Vol. VI, 1914, p. 297.

In the case of leguminous plants, an adequate supply of air for the root is even more important than in other crops. As is well known, these plants are provided with special root factories (nodules) in which, by means of bacteria, atmospheric nitrogen is worked up into complex nitrogenous substances which the plants can use as food. Both oxygen and nitrogen are essential raw materials for these factories and must, therefore, be provided if these plants are to thrive. This can only be done by efficient soil ventilation and by the provision of ample means of gaseous interchange between the soil and the air.

During the last nine years, a large number of observations on soil ventilation in India have been accumulated by the writers. These have been made for the most part at Pusa in Bihar, at Lyallpur in the Punjab and also at Quetta in Baluchistan, at all of which places opportunities of gaining first-hand experience in the cultivation of crops have been obtained. In addition, advantage has been taken of many tours, in the plains and in Central India, to study the cultivation of Indian crops under widely differing circumstances. In many cases, results have been noticed which are most easily explained by the want of an adequate supply of air in the soil. The present paper thus contains, not only direct experiments on soil aeration, but also a good many observations on matters dealing with ventilation, which have not yet been fully investigated and in which at least two factors—oxygen and carbon dioxide—may be involved. Much detailed investigation of the gases in the soil as well as numerous direct and accurately controlled experiments on the plant itself will be necessary before a full explanation of the many results of want of soil ventilation can be put forward. While the detailed scientific explanation of the case is not absolutely complete, there is no question as to the reality of the main facts themselves and of their bearing on crop production. A large amount of progress can be made at once in Bihar, in Baluchistan and possibly also in many tracts in the plains, by increasing the air supply in the soil. These methods are indicated, partly in the present paper and partly in a paper, now in preparation, on soil erosion and surface drainage.

One objection may possibly be made to the present presentation of the facts, namely, the small number of direct experiments of a laboratory kind, such as are most usual in papers on Agricultural Science. The conclusions reached have been obtained, for the most part, in another way, namely, by long continued and almost daily observations on the growth of crops combined with much reasoing and thought on the phenomena observed. The knowledge which comes from continuous contact with growing plants is of course not of the same order as that which may be

called "test-tube evidence," but we venture to think that, rightly used, it is of the greatest value to the investigator and can be employed in advancing crop-production. After all, it is on this kind of evidence that the greatest advances in British Agriculture have been made, both as regards crop-production and in the improvement of stock. It is the method used by the older naturalists, such as Schimper, with results which are known to all. It is allowable for an experiment station worker to acquire an intimate knowledge of the growth of plants and to use this information in advancing Indian Agriculture.

II. OBSERVATIONS IN BIHAR.

1. The agricultural factors in Bihar.

The agricultural factors in Bihar are, to a great extent, similar to those which obtain in most of the region known as the Gangetic alluvium. An account of the most important conditions of crop growth at Pusa in Bihar will therefore serve to illustrate the limits imposed by the seasons over a very large area of Northern India. Local modifications naturally exist, but, taking a broad view of agriculture in the plains as a whole, the sequence of climatic changes, at any one station, applies generally to the whole region.

The chief agricultural factors in Bihar are—rainfall, temperature, humidity and soil. In the following, these factors are dealt with generally, and Pusa has been selected as an example as regards the actual figures relating to rainfall, temperature and humidity.

Rainfall. The bulk of the rainfall in Bihar falls in the months of June, July, August and September. The precipitation, however, is hardly ever regular during this period. Almost every year there are one or more heavy bursts of rain during which as much as twelve inches may fall in twenty-four hours. Sometimes, a succession of these heavy falls occurs in the same month when the total may easily exceed twenty-five inches for this period. The onset of the rainy season is sometimes irregular and the monsoon may not begin till July. Breaks, of irregular length, also occur during the rainy season while its termination shows as much unevenness as its inception. The vagaries of the Indian monsoon are well known, and, in the irregular and uncertain distribution of rain, Bihar participates though not to so marked an extent as the regions of the Gangetic plain to the north-west. The rainfall at Pusa for the last five years is given in Table 1 as well as the monthly averages for this period.

TABLE 1.

Rainfall at Pusa during the years 1910-14.

Month.	1910.	1911.	1912.	1913.	1914.	Average.
January	0·01	0·27	0·13	0·00	0·00	0·08
February	0·02	0·00	0·11	1·44	0·97	0·51
March	0·07	0·57	0·80	0·43	0·11	0·39
April	0·14	0·44	1·18	0·01	1·94	0·74
May	0·41	0·33	3·14	7·00	1·86	2·55
June	7·46	11·79	4·61	17·71	4·21	9·16
July	9·34	9·21	14·48	10·22	10·19	10·69
August	6·88	17·98	9·63	18·57	28·83	16·38
September	3·70	8·09	3·33	8·17	6·13	5·88
October	4·16	3·13	0·16	1·07	0·09	1·72
November	0·14	0·71	4·03	0·00	0·00	0·98
December	0·00	0·00	0·00	1·13	0·03	0·23
TOTAL .	32·33	52·52	41·60	65·75	54·33	49·31

Besides the monsoon rainfall proper, falls often occur at the end of September and the beginning of October. These are known as the *hathia* and are of great local importance in connection with the sowing of the cold weather (*rabi*) crops. A certain amount of rain also falls during the cold season and it is not uncommon to have rain in February during the ripening of the *rabi* crops. Storms, often from the west, may occur during the hot season, particularly after long continued east winds, and, about the end of May, there is sometimes a well marked fall, known as the small monsoon (*chota barsat*), advantage of which is taken to sow maize and other monsoon (*kharif*) crops.

Looking at the monsoon in the plains as a whole, the total rainfall decreases in amount from Lower Bengal to the west of the United Provinces. With the diminution in total precipitation, the irregularities in distribution also become more marked so that, in most of the United Provinces, the crops are insured by some form of irrigation—by wells in

Oudh and by canals in the Western Districts. The supply of moisture in the soil in most of the submontane regions of the alluvium is however adequate, partly because the rainfall in this tract is better distributed and more certain, partly owing to the fact that the subsoil water is comparatively near the surface and partly to the fact that the soils of this tract are somewhat heavy and retentive.

Associated with the rainfall are changes in the position of the underground water-level. When the monsoon begins, the level of water in the wells and rivers is at its lowest. As the rains proceed, the rivers fill up and there is a general rise in the water-level which is shown by the upward movement in the wells. This rise in the general water-level is naturally most pronounced towards the delta of the Ganges, but it is also very well marked in Bihar. In the rain-inundated areas, and in Bihar in years of flood, the level of the ground water is only a few feet below the surface of the highest lands. This rise of the ground water must affect the soil atmosphere and must slowly drive much of the soil air past the roots of the growing crops into the free atmosphere. In cases of sudden inundation in the monsoon, caused by the bursting of embankments, the loss of air goes on for some time until the whole of the soil is completely waterlogged. As the monsoon expires, the water in the rivers subsides and, at the same time, there is a general fall in the level of the ground water. By the middle of October, this fall is well marked and the process goes on till the hot season in March and April when the rivers in Bihar reach their lowest point. This movement of water must cause a continuous indraught of air into the soil to fill up the vacant space and thus there is for *rabi* crops a continuous passage of air past the roots of the crops into the deeper layers of the soil. These movements of the soil water therefore tend to promote the aeration of *rabi* and to decrease the air supply available for monsoon crops.[1]

Temperature. Irregularities in temperature, similar to those in rainfall, occur in Bihar as well as in other parts of the plains. There is, however, a general well marked sequence of events. In Bihar, the temperature rises rapidly early in February and this continues during March, April and May till the rainy season sets in in June. The *rabi* crops ripen under a rapidly ascending temperature and, at harvest time, high winds often blow from the west when the humidity of the air rapidly falls. All surface rooted crops are soon dried up and only deep rooted

[1] Besides the movements of the ground water, the aeration of the soil depends on other factors such as expansion and contraction due to changes in temperature, evaporation of soil moisture and changes in the barometric pressure.

crops, like indigo and established trees, are able to grow during this period without artificial irrigation. During the monsoon, the maximum temperature falls far below that of the hot season, but, at the same time, the minimum temperature rises, a fact which confers on the climate of this period its well known attributes. In October, the temperature begins to fall and this process goes on till January which is the coldest month of the year. The average maximum and minimum temperatures during the year at Pusa are shown in Table 2.

TABLE 2.

Temperatures at Pusa during the years 1910-14.

Month.	1910.		1911.		1912.		1913.		1914.		AVERAGE.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	73·8	45·8	74·6	51·2	73·9	49·2	75·1	46·2	75·1	48·2	74·5	48·1
February	80·8	48·8	72·5	48·7	81·2	53·0	77·4	52·7	79·3	52·7	78·2	51·2
March	90·6	58·2	86·2	59·0	90·2	56·8	86·4	57·1	88·1	58·9	88·3	58·0
April	100·2	68·7	98·2	68·8	92·1	67·9	102·7	70·5	93·5	66·7	97·3	68·5
May	99·9	75·5	99·5	75·5	98·0	74·5	96·6	72·4	97·3	74·6	98·3	74·5
June	93·8	78·2	92·5	77·4	96·8	76·9	89·4	75·2	98·3	77·9	94·2	77·1
July	89·7	77·7	92·1	78·1	89·5	77·9	91·6	78·4	91·2	78·1	90·8	78·0
August	90·4	79·2	89·5	77·7	90·6	74·8	89·9	77·7	88·8	77·4	89·8	77·4
September	90·1	78·3	88·9	76·6	91·9	75·4	89·7	76·6	91·2	76·9	90·4	76·8
October	88·1	70·8	87·7	71·4	91·2	69·1	87·9	69·9	88·9	66·4	88·8	69·5
November	81·5	58·6	79·8	58·1	80·4	57·4	82·1	55·7	84·3	56·3	81·6	57·2
December	75·3	48·1	73·4	48·1	74·3	49·4	73·2	49·9	77·8	48·6	74·8	48·8

Besides the hot season from March to early June, temperature influences production markedly at two other periods. The cold weather crops like wheat should not be sown till the temperature of the soil has fallen sufficiently to prevent harm being done to the seedlings. In the very cold weather of December and January, the fall in temperature affects the rate of growth. The shortness of the days at this period and the frequent foggy weather also assist in checking growth.

Humidity. Generally speaking, the humidity of the air in North Bihar is high, particularly during the monsoon and till the cold season has set in. Heavy dews occur whenever the range of temperature favours their formation except in the hot season after a succession of dry west winds. The figures showing the average humidity are given in Table 3.

TABLE 3.

Humidity at Pusa during the years 1910-14.

Month.	1910.	1911.	1912.	1913.	1914.	Average.
January	90·2	90·8	92·3	88·2	91·6	90·6
February	76·7	78·7	82·8	87·7	83·5	81·9
March	60·6	66·2	59·6	61·7	61·9	62·0
April	53·7	57·9	68·1	51·6	64·2	59·1
May	64·3	69·8	70·4	67·4	70·9	68·6
June	81·2	80·5	78·8	86·8	73·7	80·2
July	88·3	86·2	88·5	84·3	86·9	86·8
August	85·6	90·3	87·6	88·2	91·3	88·6
September	87·6	88·4	82·2	88·3	83·5	86·0
October	84·1	87·1	76·5	84·9	80·9	82·7
November	83·7	86·9	84·1	86·3	84·4	85·1
December	85·3	91·9	89·8	91·2	87·1	89·0

Soil. In extensive alluvial plains, like those of the basin of the Ganges, there is naturally not the same range in soils as on many other geological formations. Such differences in texture and physical condition as exist are, for the most part, associated with position. The high-lying lands are usually lighter and opener in texture than the heavy soils in the low-lying areas which often grow rice. These differences are largely bound up with the loss of fine soil-particles which is going on continually, not only in any one area, but also in the Gangetic system as a whole. Locally, fine soil is being washed from the high-lying lands and deposited in the low rice areas. In this way, the rain washed areas tend to become light in texture while the heavy condition of the rice fields is maintained. Looking at the plains as a whole, a vast amount of fine silt is carried down to Lower Bengal by the Ganges and deposited in the deltaic regions in the form of new land, which, after many years, becomes cultivated and grows uncertain crops of rice. This enormous transfer of fine soil by the Ganges and its tributaries from the area drained by this river represents a great loss of agricultural capital and is a great drain on the natural resources of the country.[1]

[1] This economic drain can be prevented by methods well within the means of the ryot. These are described in Bulletin No. 53 of the Pusa Institute on *Soil-erosion and surface drainage.*

In Bihar and the newer alluvium in Bengal, the distribution of crops depends for the most part on position. The low lands are in rice, while the high lands, which are often marked by lines of villages, carry crops like tobacco, *rahar* (*Cajanus indicus*), barley, wheat, maize and numerous millets, turmeric, castor oil, chillies and Java indigo. Mangoes and other trees are also confined to the high lands. A journey across the country in Bihar, at right angles to the rivers, would carry the traveller across successive low-lying rice flats, alternating with slightly higher, broad ridges, covered with the above-mentioned crops and interspersed with mango groves and villages. The surprising feature of this regular diversity is the small differences of level between the rice flats and the ridges—differences of level of more than four or five feet being rare.

2. Plant growth in Bihar.

A brief account of the main phenomena of growth in Bihar is necessary before the reader can fully understand the agricultural bearing of the special cases dealt with in the following section. It will be convenient to deal with the general manifestations of growth under three heads—monsoon crops, cold weather crops and trees.

Monsoon crops. The sowing of *kharif* crops, like maize and millets, is always made as early as the rains permit. The ryot never waits but sows the moment sufficient rain has fallen to ensure the establishment of the seedlings. If the rains are late, the crops are often sown in the dust and the seed left to germinate when the first showers fall. If sowing is deferred till the rains have well set in, the results are poor and the late sown crops always fall far short of those sown at the opening of the monsoon.

As a rule, monsoon crops give the best results if the rain is well distributed and is below the average. A succession of heavy falls is particularly harmful, while the rise of the ground water nearly to the surface, in years of long continued and heavy rain, checks growth almost entirely. In flood years, most of the inundated crops are completely destroyed.

The surface skin (*papri*) which forms after rain in the monsoon, checks growth a great deal. This surface crust is broken up as far as possible during the early rains, with immediate benefit to the crops, but, as the monsoon progresses and the falls increase in volume and frequency, the whole of the surface soil becomes wet and compacted, often for long periods. In such circumstances, surface cultivation cannot be attempted, as the land is too wet, and the crops suffer. In

general, it may be said in Bihar that want of air in the soil does infinitely more harm to *kharif* crops than want of water.

Cold weather crops. The temperature of the soil appears to be the factor which really regulates the sowing time of *rabi* crops. As soon as the land has cooled down sufficiently, these crops are sown and there is great risk in sowing too early, particularly in the case of wheat. Early sown wheat often rots after germination due to the heat of the soil.[1]

The greatest damage of all is done to *rabi* crops by the formation of surface crusts by rain. The plants soon stop growing, and, if the crust is well developed, they turn yellow and take on a characteristic starved appearance. Immediately the *papri* is broken, either by hand or by lever harrows, an immediate improvement takes place, the yellow tint changes to dark green and rapid growth is resumed. Surface crusts formed by rain in February are very harmful and always interfere with the ripening process. The best crops have been obtained at Pusa when no rain has fallen between sowing and harvest. It is naturally not possible to break the late *papri* in the case of ripening crops like wheat or barley and thus the supply of moisture and of soil air falls off before the grain has fully matured.

The most important point about *rabi* crops like tobacco in Bihar is that most of the growth has to be compressed into a period of six or seven weeks. By the end of October, the seedlings are established, while, about the middle of December, the fall in temperature begins to check growth. There is thus a period of six weeks for growth, and, provided the soil is in the right condition, the rate of growth during this period is prodigious.

Trees. The beginning of the hot season is one of the greatest periods of growth in the case of established trees. The cold months of December and January are a resting period for most trees and leaf-fall is common in January. The rise of temperature in February is at once marked by the formation of new leaves, shoots and flowers in the case of many trees. This rapid growth goes on well into the hot weather. Another period of growth coincides with the early monsoon phase, but, after the

[1] The importance of the sowing rains (*hathia*) in Bihar appears to depend more on their cooling effect on the soil than on the actual moisture added to the land. In 1914, when the *hathia* failed in Bihar, and when the rains ceased early over a large area of the Gangetic alluvium, there were numerous references, in the crop reports, to the damage done to the young wheat by white-ants and heat. This was probably caused, in the first instance, by the crop having been sown in too warm a seed-bed. This raises the question of the more extended use, in such seasons, of irrigation prior to sowing for the purpose of cooling down the soil low enough for the wheat to thrive. At Pusa this year, the land was exposed for a few hours, by means of iron ploughs, before sowing, so that the soil cooled by the evaporation of some of the moisture. The results were beneficial and no wheat was lost by heat or white-ants.

rains are well established, and the level of the ground water has risen considerably, growth slows down. This result is certainly curious for all the factors of growth seem to be present but nevertheless little or no growth takes place. When the monsoon has ceased, when the level of the ground water has fallen and the surface soil has dried a little, growth begins again in October and goes on till the temperature begins to fall in November. The almost complete cessation of growth during August and September coincides with the falling off of gaseous interchange between the soil and the air. At this period, the subsoil water has risen to about its highest point, the surface soil has become exceedingly compacted by heavy falls of rain, cultivation is impossible, as the ground is too wet and the whole of the upper layers of the soil have become waterlogged. There is no adequate air supply for the roots and exchange of gases between the air and the soil is difficult. All growth tends to become arrested. Further, all vegetation at this time takes on a very unhealthy appearance. A change takes place as soon as the subsoil water falls and ventilation is possible. Active growth is resumed which goes on till the fall in temperature brings about another resting phase.

3. The relation between soil-ventilation and agricultural operations.

Many examples, illustrating the importance of air in the soil, have accumulated at Pusa during the past nine years. As far as practicable, these have been grouped together, and, whenever possible, the agricultural bearing of the observations and experiments has been indicated.

Manuring. In considering the manuring of the alluvium of Bihar, the structure of the soil must be borne in mind as well as the demands of the plant for inorganic food materials. The most favourable structure of a soil for crops is one which is not too loose to retain the water which is necessary for growth and yet is not so close as to have its pores so filled with water, under normal conditions, as to prevent the access of the necessary amount of air to the roots. The ideal condition of a soil is one which can be described as highly porous and in which the greatest amount of food materials and water can be retained without losing the capacity for absorbing air.

In the close Bihar alluvium, any system of manuring is of little value unless the porosity of the soil is increased. This is a much more important matter than in England where many of the soils contain a wide range of particles and are naturally highly porous. The best means of producing this condition in most soils is by the addition of

stable manure which increases the pore space and also promotes rapid gaseous interchange with the atmosphere. Unfortunately in Bihar, the amount of farm-yard manure is small as most of the straw is used to feed cattle while the dung is burnt as fuel. On this account, indigo *seeth* is of particular value as by its use not only is the soil manured with vegetable matter, in the proper condition for rapid decay, but, at the same time, it is rendered much more porous. The air supply of the roots of the growing crop is increased and the soil bacteria are provided with abundant oxygen. *Seeth* is a far better manure for tobacco than oil-cake and indeed than farm-yard manure itself. The explanation of the superior value of *seeth* is probably partly due to its great power of aerating the soil and of providing the rapidly growing tobacco with the large amount of air its roots are known to need. *Seeth*, however, has one disadvantage as an aerating agent, namely, its want of permanence. After three or four years the effect of a good dressing of *seeth* dies away.

Green-manuring is another valuable substitute for farm-yard manure and *seeth*. One disadvantage, however, has to be got over in practice before the best results of improving the texture of the soil by this means can be taken up on the large scale. During the growth of the green crop—usually *sanai* (*Crotalaria juncea*)—the soil air is used up by the roots and large quantities of carbon dioxide are formed. More air is again required for the decay of the crop. By the time the field is ready for transplanting the tobacco crop, towards the end of September, there is a great danger that the air supply in the soil has been drawn upon to too great an extent to ensure the rapid growth of the tobacco crop. Probably this disadvantage can be minimized by allowing the *sanai* to wilt on the ground for a few days before being ploughed in and also by frequent and deep cultivation with iron ploughs for some time before the tobacco is transplanted. The wilting of the *sanai* introduces a good deal of air into the plant and experience shows that rapid decay is promoted by this means. The frequent and deep stirring of the soil before the tobacco is transplanted also releases much carbon dioxide and, at the same time, promotes copious aeration and rapid nitrification of the organic matter.

It is exceedingly probable that the many failures with green-manuring on the alluvium are due simply to interference with the air supply of the roots of the next crop. It is well known that the best results are obtained by this method of manuring on light, open soils, that is to say, on soils naturally highly porous and amply supplied with air. On the other hand, in heavy soils, and in lands which have been water-

logged, negative results are the rule, as far as the next crop is concerned, although the green-manure improves the texture of the soil. In such cases, there is obviously insufficient aeration for the needs of the decaying green-manure and for the roots of the next crop. The result is oxygen starvation and a poor yield. If, however, the green-manuring is confined to high, well-drained lands, and, if attention is paid to frequent and deep cultivation after the green crop is buried with the object of aerating the soil as much as possible, it is more than likely that green-manuring will prove a much better method of soil improvement than is at present the case.

During the year 1913, an experiment was carried out at Pusa which threw considerable light on the relation between soil aeration and green-manuring. Three plots were green-manured with *sanai* on July 15th, August 7th and August 28th, respectively. On September 24th, a strip down the middle of these plots was subsoiled to a depth of about twelve inches two days before the tobacco was transplanted. The arrangement of the plots is shown in the following diagram :—

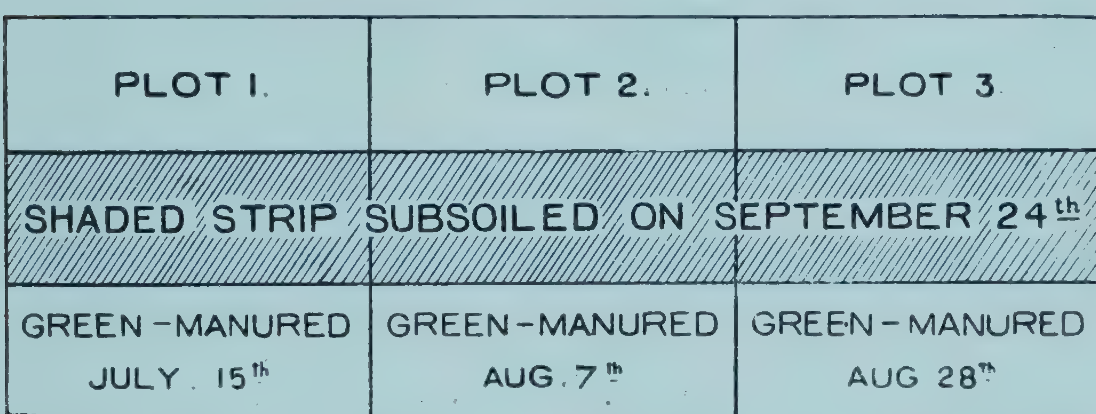

FIG. 1. Green-manuring experiment at Pusa in 1913.

The results of the experiment were very striking. The tobacco in plot 1 grew very rapidly from the beginning and gave the best results. Plot 2 was not so good while plot 3 was poor. In all the plots, particularly in plots 2 and 3, subsoiling gave a marked crop increase and the appearance of the tobacco on this strip suggested a liberal dressing of nitrogenous manure. The subsoiling probably released a portion of the carbon dioxide in the soil, which had accumulated as a result of the decay of the green-manure,[1] and also directly increased the supply of oxygen. The extra air-supply would have its effect on the nitrification of the organic matter and also on the development of the roots of the

[1] Kidd, *Proc. Roy. Soc. B.*, Vol. 87, 1914.

tobacco crop. The changes in the soil gases in green-manuring under Indian conditions require to be investigated and the results are almost bound to prove of interest. It is exceedingly probable that the success of green-manuring on the alluvium will depend on the degree to which the soil can be aerated towards the end of the decay of the *sanai* and before the sowing of the next crop. It is clearly not sufficient merely to plough in a green crop and leave it till sowing time comes round. It must be borne in mind that the next crop depends on an adequate air supply as well as on moisture and food materials.

Besides cultivation as a means of aerating the soil after the decay of the green crop, there is another possible method which gives certain results. This consists in mixing into the soil fragments of tile or bricks. The advantage of this method is that the improvement in aeration is a permanent one and is not destroyed by the next monsoon. The agricultural significance of this method of aeration is shown every year by plot No. 3 of the Southern Trial Ground in the Botanical area at Pusa on which the most striking results with *sanai* have been obtained hitherto.[1] This plot contains a fair proportion of tile fragments and on this soil excellent crops of tobacco are always obtained. The only question which remains to be decided about this method of aeration is the cost and whether fragments of bricks or tile can be suitably mixed into the soil at a reasonable outlay. A number of experiments on this subject are in progress at Pusa, the results of which will be published later.

Fallowing. The effects which follow a monsoon fallow in Bihar are well known. All *rabi* crops show the benefit at once and in the case of tobacco it is the rule never to precede this by any form of monsoon cropping. These beneficial effects follow from a variety of causes and are principally due to conservation of moisture and mineral food materials including nitrates, the destruction of weeds and also the air supply to the roots.

A few years ago at Pusa, an attempt was made to grow tobacco after Java indigo. The first cut was taken in July when the field was manured with indigo *seeth* through which the old stumps sent up the second crop. This was taken in August when the stumps were removed. After a thorough cultivation, tobacco was set out about the end of September. Moisture was abundant and everything seemed favourable for a really good crop. The result, however, was somewhat disappointing. Towards the end of the growing period, the plants developed slowly and did not ripen off sharply. This is always the case with this crop if the

[1] The results with *sanai* on this plot are illustrated in the *Agr. Jour. of India*, Vol. VII, 1912, p. 80.

air supply to the roots has been interfered with to any extent. Possibly a better result could have been obtained had more attention been paid to deep and frequent cultivation after the indigo crop was dug up, but the fact remains that, with the ordinary cultivation carried out in the Botanical area, the aeration of the soil was not sufficient for tobacco.

Hot weather cultivation, which is spreading to a great extent in the alluvial soils of India, is an essential part of a fallow. This exposes the soil thoroughly to the hot, dry winds of March and April and so kills out many weeds including *dub* grass (*Cynodon dactylon*). By its means, the surface soil is thoroughly aerated and the indraught of air into the subsoil, which must follow the fall of the water level, is promoted. The result is that, on the advent of the monsoon, there is an abundant supply of air for the soil bacteria and also for the needs of the monsoon crops. But for this air, the extraordinary rapid growth which takes place after hot weather cultivation when monsoon crops are sown at the beginning of the rains, would not be possible.[1] It is a curious result that the nitrates formed at this period are not washed away by the heavy rains which follow. Whatever movements of nitrates may take place in the soil, they are always available after a fallow for the *rabi* crop in October.

Consolidation of the surface soil. As a continuous air supply to the roots of a growing crop depends on constant gaseous interchange between the soil and the atmosphere, and, as this exchange takes place best only when the soil is porous, it follows that any undue consolidation of the surface must be harmful as this must tend to cut off the oxygen supply of the roots.

An excellent example of the ill-effects following over-consolidation occurred at Pusa in October a few years ago. In sowing a field of pure line cultures of wheat behind the plough, it was necessary to pass the cattle several times over the headlands with the result that two strips, about four feet wide, on the east and west borders of the field became somewhat consolidated. The first effect of this was to bring up the soil moisture to the surface. The second result was that, while the seed sown in the field germinated and did well, only a few of the grains in the consolidated strips sprouted while none of these plants established themselves but died off during the first two or three weeks. The result must have been due to the exclusion of air and proves that overpacking and rolling after sowing does harm to the crop.

[1] Besides its use in aeration, hot weather cultivation probably alters for a time the bacterial flora in the soil.

Perhaps the best example of the ill-effects of over-consolidation on wheat after sowing occurred at Pusa in 1912. In that year the *hathia* failed, and it was thought that the opportunity was a good one for trying the effect of the Canadian subsoil packer in bringing up the moisture so as to increase the tillering power of the wheat. A large amount of the crop was compacted twice and everything went well until two unexpected heavy storms of rain passed over Bihar. This, coming after the packing, consolidated the soil to such an extent that it was feared that the whole crop would be lost. It was saved, to some extent, by harrowing the surface, but in that year the lowest yields on record were obtained at Pusa, the consolidated area stood badly and the grain was very poor. On the other hand, the best samples of grain, the highest yields and the best standing crops have been obtained when iron ploughs have been put through the fields before sowing and when the surface has been left rather loose. After growing wheat in Bihar for nine years, we are convinced of the importance of aeration for this crop and equally convinced that over-consolidation from any cause is very harmful.

Numberless other examples of the harm caused by over-consolidation have been observed at Pusa. In the course of the plant-breeding work, it is often necessary in picking off insects, in labelling plants, in removing suckers and in studying the plants to tread a good deal between the rows. It has been found necessary to limit this as far as possible and to cultivate deeply by means of the *kodar* (a kind of mattock) at least once or twice during the life of the crop. The effect is always instantaneous and, even if a few roots are broken off in the process, the gain resulting from increased aeration is at once seen in the renewed growth and vigour of the plants. In crops like tobacco, which need a great deal of air, it is essential after any work has been done among the plants, to have the surface stirred as deeply as possible with the *kurpie*. Much less cultivation is needed in tobacco grown for leaf than in the plant-breeding plots, where the ground is consolidated a good deal by treading.

A great compressing agent in Bihar is a heavy and long continued monsoon rainfall, particularly on the low-lying lands. The effect is to make the whole of the upper layers of the soil run together into a solid mass and to fill up most of the pore spaces with water and fine particles. So great is this consolidation, that some judgment is required in preparing these heavy lands for wheat in October and producing a fine tilth without too many clods. Some years ago, one half of the continuous wheat plot at Pusa was ploughed deeply with iron ploughs in

October and afterwards reduced to a fine tilth. The other half was cultivated with the country plough. There was a great difference in the growth of the wheat crop on the two halves of the field. On the half which was ploughed deeply in October, the wheat rooted well, had stronger straw and stood better than that on the other half. Further, the sample on the iron ploughed plot was much better grown and bolder than the other. The only difference in the treatment of these two halves was the extra aeration before sowing on the deeply ploughed plot. Some crops like *rahar* (*Cajanus indicus*) and Java indigo, sown for seed in August, have to pass through a portion of the monsoon with the result that the porosity of the surface soil is almost entirely destroyed when the rains cease. Both these crops require oxygen for the roots and nitrogen gas is also essential for the work of their root nodules. Artificial aeration in October has an instantaneous effect. Java indigo, cultivated with the spring-tine cultivator, at once grows rapidly and strongly while the benefits which follow the cultivation of *rahar* are well known to every cultivator in Bihar.

All silt-like alluvial soils are particularly liable to run together on the surface after rain and to form impervious crusts. The Bihar soil is no exception to the rule and the breaking of the crust (*papri*) is a recognised operation in agriculture. Indeed the people seem to be born with a special *papri*-breaking sense. The formation of these crusts at once interferes with the aeration of the roots and, as soon as the air supply in the soil is used up, growth stops. The presence of an excess of carbon dioxide round the roots seems to hasten the first stages of asphyxiation which can be seen by a slow yellowing of the leaves. This is followed by a gradual wilting of the crop and the plants often die without setting seed. The moment the *papri* is broken and gaseous interchange is renewed, there is an almost instantaneous effect. The leaves turn dark green and the arrested growth recommences. The result is naturally most marked at periods of rapid growth and in the case of crops like tobacco and indigo which need a large quantity of air.

Although the people understand the need of breaking the *papri* in the case of established crops, they do not realize that young seedlings require air. The Indian *malis* never seem to be able to raise good seedlings and their failure in this respect is mainly due to the fact that they do not understand that the roots must breathe. Their remedy is to apply more water with the result that their seedlings develop no proper root system and thus do not stand the shock of transplanting well. The secret of success in this work is to give the seedlings as much air as possible by keeping the surface crusts of the seed boxes well broken up

by means of a small bamboo peg. Deep rooting and hardiness are also promoted if the regular watering is stopped occasionally for a whole day.

There is a great need in Bihar for an efficient *papri* breaker which can be drawn by cattle and which can be passed over young crops like wheat or indigo without damaging the plants. The lever harrow is an excellent device for this purpose as the slope of the tines can be altered to almost any extent. Since their introduction at Pusa three years ago, they have been taken up on many estates and have given excellent results. For indigo cultivation during the hot weather they have proved indispensable.

Earth mulches. In general, the value of a mulch lies in its power of conserving moisture or warmth. In Bihar, however, earth mulches give a supply of well aerated earth to plants and their effect in certain cases is very great.

The ordinary *dub* grass (*Cynodon dactylon*), which is used for lawns and also for fodder purposes, grows exceedingly well at first when planted in cultivated earth. After a time, however, growth slows down, the *dub* gives place to other species and finally, if undisturbed, the lawn would become a mass of rough coarse thatching grass[1] mixed sometimes with small *sissoo* trees (*Dalbergia sissoo*). Left to itself, *dub* does not maintain itself except in places like river banks where it receives annually new deposits of silt. When the silt is sandy, the *dub* grass seems to thrive best. If, however, a dressing of ordinary soil is spread over *dub*, when growth begins to slow down towards the end of the monsoon, there is an immediate change. A new growth, of a dark-green colour is produced and the dressing of ordinary earth acts like nitrogenous manure. Possibly the exposure of the soil to the sun increases nitrification. Similar but slower results are seen when the *dub* turf is pared off with the *kurpie* in the country fashion for fodder. The addition of the dressing of soil as well as the paring off of the turf promotes aeration and possibly nitrification as well. Water is not a limiting factor as in all these cases of arrested growth the soil is quite moist beneath the turf.

In the raising of tobacco seedlings in the second half of the monsoon, difficulties arise due to the loss of soil round the plants by rain wash and also as a result of the beating down of the soil by the rainfall. A great improvement always takes place after cultivation if more soil is sprinkled over the bed to replace that which is lost and to support the plants. The good result of the earth mulch is no doubt due to several

[1] These rough grasses which displace *dub* in Bihar are composed of a mixture of *dabhi* (*Imperata arundinacea*) and *rarhi* (*Saccharum spontaneum*).

factors, but moisture conservation is not one of them, as the result is to be seen during weather when moisture is abundant. The new supply of well aerated soil increases the air supply of the roots of the seedlings.

An undoubted opening for earth mulches exists in Bihar in the case of surface rooted *kharif* crops like maize, which frequently suffer from want of air. When planted in lines rather far apart and when earthed with a ridger drawn between the lines, not only is the *papri* broken up, but a new supply of well aerated earth is placed round the roots. The result is, as would be expected, a greatly increased crop.

Perhaps the best examples of the aerating value of earth mulches in Bihar is to be seen in the cultivation of vegetables like cabbages and cauliflowers. The roots of these plants require large quantities of air and a loose, rich earth. This result is best obtained by continually moulding the roots with fresh earth so that finally each plant stands in a cone of soil in which the fine roots ramify. The oftener this moulding is done the better the result. Tobacco plants are also mulched with fresh earth drawn round the plant, but this is not done to the same extent as in the growing of large cauliflowers and cabbages.

Methods of aeration. Besides the cultivation and the breaking of surface crusts, there are several other natural methods of soil aeration some of which are of the greatest value.

Many plants aerate the soil and thus confer direct benefits on succeeding crops. *Rahar* (*Cajanus indicus*) is perhaps the best example of a crop which acts as a natural soil aerator. The root system of this plant is considerable, the tap root is long and grows down into the soil to a great depth. The lateral roots break up the soil in all directions and when they are removed by white-ants (*Termites*), after the crop is reaped, a system of small tunnels is left which helps materially in ventilating the soil. The effect of this aeration on the succeeding tobacco crop is very great and the benefit of the *rahar* tobacco succession is well known to the people. The cultivation given to this crop after the monsoon also helps in the aeration, while the organic matter added to the soil by the fall of its leaves and flowers also assists in the same direction. *Rahar* is the subsoil plough of the Bihar ryot.

The current ideas in Bihar on the best method of converting rough grass land (*perti*) into arable cultivation should be mentioned at this point. Planters say that hardly anything will grow on *perti* land when it is first broken up and they recommend sweet potatoes to begin with. After this, they say there is no further trouble and almost any crop can then be grown. There is no doubt that under rough grass the soil gets very little aeration and is in a thoroughly packed and sour condition.

Thorough aeration is necessary for such land and this is given both by the preparation for sweet potatoes and also by the complete stirring of the soil which takes place when the crop is reaped. The sweet potato manages to thrive in a soil in which many other plants would be asphyxiated on account of the aeration caused by the swelling of its roots. This bursts open the land and lets in air. The gradual production of the root swellings acts like a mild explosive and shatters the soil. The sweet potato is the Bihar method of dynamiting the soil.

The most startling results of natural aeration are, however, to be seen after trees have been felled or when holes (such as the brick soaking tanks used in building operations) have been filled with new earth. When a tree has been cut down and the roots have died, the white-ants become active and proceed to eat out the whole of the cylinder of wood, leaving the bark behind. The result is that there is a perfect network of connecting tubes under the surface which greatly promote the aeration of the soil and of the roots of crops. The effect of this becomes very marked about a year after the trees are cut down and the results on the crop are similar to those obtained by heavy dressings of nitrogenous manure. The increased aeration obviously acts in two ways. In the first place, a plentiful supply of air to the roots is supplied. In the second place, the formation of nitrates by the soil bacteria is considerably increased. There is a very good case in the Botanical area at the present moment of the effect of old roots on succeeding crops. A line of *sissoo* trees, which previously ran parallel to the east side of No. 1 Barah plot, was cut down in 1910. In 1911, it was observed that the edge of the plot next to the former line of trees was becoming exceedingly fertile. The effect is still more evident during the present year and the wheat crop on the east side of this plot will have to be cut back to prevent lodging later on. This result is a consequence of the work of the *Termites* in removing the wooden cores of the roots. These insects are always attracted by old wood which they rapidly devour. In addition to assisting in the transformation of vegetable matter into humus, these insects are most useful as aerating agents and their systematic destruction, as is sometimes advocated, would, if successful, only lead to great loss to India.

The aeration effects which follow from the filling up of holes at Pusa are very striking. Particularly is this the case when these holes have resulted from building operations such as soaking tanks for bricks, or mortar mixing wheels (*bail chucki*). The workmen who level up these places after the buildings are finished are not very particular and the soil used in filling in always contains pieces of brick. The filling is

therefore highly aerated soil, in which the air giving materials are permanent. The result is that if crops or trees are planted over these spots they thrive to an extraordinary extent. Good examples are to be seen in the avenue on the west side of the Phipps' Laboratory and in the old brickfield which has now been transformed into arable land. In the spots in question, the roots of the plants are aerated while the nitrifying organisms in these soils, being supplied with plenty of air, are producing nitrates in abundance and to a much greater extent than the bacteria in the poorly aerated soil near. The consequence is that these filled in places have the appearance of having been heavily manured. The manure however is simply oxygen gas.

The aerating value of brick fragments (*roras*) and of pieces of tile (*thikara*) in connection with green manuring with *sanai* has already been referred to (p. 14). There is little doubt that these substances are of the greatest use in permanently improving the soils of Bihar. The only points which remain to be settled are the cheapest method of mixing and the best material to use. For valuable crops like tobacco, it might pay to dress the land with *roras*, *surkhi* (small pieces of brick) or *thikara*. Experiments on this subject are in progress at Pusa and an attempt is being made to compare the cost of the treatment with the increase in fertility. Peaches certainly thrive best on land which contains *thikara*. There is evidence that the results obtained by sterilizing the soil of tobacco nurseries are partly due to increased aeration and that similar results would be obtained by mixing *surkhi* or *thikara* with the rich soil.[1]

Rice cultivation. The relationship which exists between the well-being of swamp rice and the aeration of the soil has been investigated at Coimbatore by Harrison[2] who has shown that the surface film of algæ and other organisms on these soils plays the leading part in the formation of the oxygen required by the roots of the rice. This investigator also states that " aeration of these soils by atmospheric oxygen is not as effective in promoting root aeration as is aeration by the water drawing through them." We have not studied rice production in any great detail in Bihar but some observations have been made on this crop. The yield of rice in North Bihar depends greatly on the *hathia* rains, and, when these fail, however good the monsoon, there are always complaints about the poor rice crop. Such complaints are common during the present year when the *hathia* failed after a heavy monsoon. Examination of the soil of the rice fields shows that there is abundance of mois-

[1] The value of *thikaras* in increasing the fertility of the soil is seen when old village sites are brought under cultivation. There is an excellent example on the farm at Sabour.

[2] Harrison and Aiyer, *Mem. Dept. Agr. in India* (*Chemical Series*), Vol. III, No. 3, 1913.

ture, nevertheless the crop is poor and the grains are not well filled. The value of the *hathia* rains seems to be to restore the activity of the algal film and to give the roots a final aeration by means of the oxygen dissolved in the water draining through them.

One common practice in rice growing in Bihar is also very probably connected with aeration. The North Bihar rice lands do not crack very much after harvest and little natural aeration can take place if the fields are left untouched through the hot weather. The ryots are most careful to dig them up by hand after harvest although the labour required is enormous. They are not likely to do this work unless it is necessary and it is probable that one of the chief effects of this is to aerate the fields so as to start the next crop of rice. Where rice lands crack after harvest, as in parts of Madras, no cultivation is done as the land ploughs itself. The rice land on the Gangetic alluvium in North Bihar however only cracks to a very small extent and cultivation is necessary before aeration can take place. The drainage of the soils of the rice areas of North Bihar appears to be assisted materially by the shells of snails. These animals live in large numbers in these rice *chars* and are said to pass the dry season in the ground. The fragments of their shells are so numerous that this material must help in the passage of aerating water to the roots of the rice.

In South Bihar, the ryots always draw off the water from their fields in October and allow them to dry before the final irrigation. This process, which is called *nigar*, is probably concerned with aeration.

Grass effects. The harmful effects, which result from grass round fruit trees at Pusa, have been described in a previous paper.[1] The results agree closely with those previously obtained by the Duke of Bedford and S. U. Pickering at the Woburn Fruit Experiment Station in England. At Pusa, the effect of grass is more pronounced on small trees than on large and is greater in the case of *dub* grass (*Cynodon dactylon*) than in that of *dabhi* (*Imperata arundinacea*). At first, the species in the grass plots was pure *dub*, but since 1910, a change has taken place and the *dub* has given place to *dabhi*. The harmful effect of this latter species on trees is not so great as that of *dub* and, at the present time, custard apples in particular seem to be able just to maintain themselves under *dabhi* while under *dub* they were rapidly killed. As *dub* responds so markedly to aeration and as it gives place to *dabhi* if left to itself, it would appear that the latter grass requires less air than *dub*. This might partly explain the fact that *dabhi* has a much less harmful effect on trees than *dub* and account for the results now shown by the custard apples.

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[1] Howard, *Bull. 16, Pusa Research Institute*, 1910, p. 15.

The precise explanation of the effect of grass on trees in some circumstances has not yet been discovered. In a recent paper, the Duke of Bedford and S. U. Pickering[1] consider that the grass roots give off a toxin which poisons the tree roots. This toxin however has not yet been isolated but its presence is inferred from the results of numerous experiments. These authors have now studied the influence of grass on other crops like tobacco and have come to the conclusion that " every growing crop results in the formation of a substance which is toxic to the growth of other plants and still more so to itself." The results obtained in the case of tobacco are exceedingly like those observed at Pusa when tobacco is waterlogged or grown on heavy lands which have been green-manured. It is well known that the roots of the tobacco crop require a great deal of air and it is also known that green-manuring results in the production of much carbon dioxide in the soil. It seems probable that the Woburn results, in which the washings from grass interfered with tobacco, may after all be due to the inhibiting effect of carbon dioxide. This may be the toxin about which so much is written and it may turn out to be the explanation, not only of the effect of grass on trees, but also of the influence of one crop on another. Experiments to test this view, in the case of fruit trees, are now in progress at Pusa.

The harmful effect of grass on fruit trees depends on the soil. In many parts of England, such as Kent, Somerset and Herefordshire, it is the custom to grow fruit under grass and no particular damage results. Many of these fruit soils, however, are very porous and the carbon dioxide produced by the grass roots might easily be able to diffuse into the air and so cause no injury to the tree roots. The soils at Woburn and Pusa however are not porous. The Woburn soils are clayey in character and are such that gaseous exchange with the atmosphere is difficult. The Pusa soil is a fine silt which packs to such an extent that *dub* grass soon dies out and other rough grasses take its place. It is clear from the present paper that the Pusa soil responds to an extraordinary extent to aeration. In such dense soils as Woburn and Pusa it is probable that the effect of the carbon dioxide produced by the grass roots would be far greater than on porous soils such as those of Kent. Before carbon dioxide is finally dismissed as the toxic substance referred to by the Duke of Bedford and S. U. Pickering, it might be worth while repeating that portion of the Woburn work dealing with this gas.

Simulated diseases. Among monsoon crops at Pusa, several cases of wilting occur which at first sight appear to be caused by some form of root disease. In reality, the trouble, in all cases, follows from the interference with the supply of air to the roots.

[1] Duke of Bedford and S. U. Pickering, *Jour. of Agr. Science*, Vol. VI, 1914, p. 157.

The so-called wilt disease of Java indigo is an interesting case of slow asphyxiation. This crop, which is comparatively new to India, was introduced into Bihar some years ago and for a time did exceedingly well, yielding heavy crops of leaf and also of seed. When, however, the present cycle of wet years set in, complaints were heard, after the first cut in July, that the indigo was attacked by disease. Increasing difficulty was experienced in obtaining sufficient seed for sowing. The trouble developed so rapidly that the area under Java indigo fell from 70,000 bighas in 1910 to about 15,000 bighas in 1913, and there seemed every reason to believe that the Bihar industry was doomed.

An examination of the wilting plants at the end of the monsoon showed that practically all the finer roots, including the nodules, had been destroyed. The large roots, however, appeared healthy but the plants possessed hardly any nodules and almost no active absorbing roots. These had been destroyed as a result of the packing of the soil by constant rain during August and September. The soil had lost its porosity and gaseous exchange with the air was stopped. In consequence, both the root hairs and the root nodules died of asphyxiation and after a time the whole crop wilted away. Only in a few cases was any seed formed in Bihar and the planters were driven to import seed at great expense to carry on the industry. The remedy for the trouble, as far as seed production is concerned, is simple.[1] By sowing the indigo specially for seed on high, well-drained lands in August, the developing root system follows the fall of the subsoil water and it is possible to give plenty of air by surface cultivation to the young crop. As soon as the monsoon is over in September (when the fall of the subsoil water promotes aeration) and provided the surface soil is broken up by spring-tine cultivators, a very heavy crop of healthy seed is obtained in the cold weather. Grown in this way the seed crop avoids wilt.

No crop responds to cultivation so rapidly as Java indigo. It is a plant which can hardly be cultivated too much. If lever harrows are passed over the crop, grown for leaf in the hot season, the response is remarkable. Rapid growth takes place and if still deeper cultivation with spring-tine cultivators is given in April and May, the growth at the beginning of the monsoon is marvellous. In this way the crop starts the monsoon with a large air supply in the soil and the advent of the wilting stage is deferred. In addition to supplying oxygen, the cultivation naturally provides the nodules with a full supply of nitrogen gas. There can be no question that the future of Java indigo in Bihar depends on soil ventilation. It is perhaps not too much to say that had attention

[1] Howard and Howard, "First Report on the Improvement of Indigo in Bihar," *Bull. 51, Pusa Research Institute.*

been paid to the growing of indigo twenty years ago, there would have been no competition from the synthetic product. Even at the present moment, the chances of the industry are most hopeful if only the planters are willing to place the cultivation of the crop on a proper basis and give up their present methods.

Two other cases of simulated diseases have been observed at Pusa. In both, the symptoms were not unlike those described in Java indigo and would be described as wilt. When *patwa* (*Hibiscus cannabinus*) and *sanai* (*Crotalaria juncea*) are grown for seed, as pure crops, very fine growth is obtained up to flowering time early in October and everything seems to go well. At this period, however, the plants begin to show signs of wilt and, if the roots are examined, it will be found that almost all the fine branches have been destroyed and hardly any root hairs can be found. The destruction of the porosity of the fine alluvial soil by the constant monsoon rain has cut off the air supply and almost complete asphyxiation of the roots has resulted. In very wet years hardly any seed is obtained.

The ryots in Bihar never sow either *sanai* or *patwa* as pure crops for seed purposes. They sow a few plants on the edges of their fields for seed and these never wilt but always set a fine crop of seed. By growing these plants on the edges of the fields, which are often slightly raised, they are well drained and their roots become aerated by the cultivation given in the neighbouring fields. Thus a crop, which is often asphyxiated in pure culture, thrives on the raised edge of a mixed field when its roots obtain the necessary air.

III. OBSERVATIONS IN THE QUETTA VALLEY.

1. The agricultural factors in the Quetta Valley.

The agricultural conditions in the Quetta valley are quite different from those of the Indo-Gangetic plain. This valley is situated at an elevation of about 5,500 feet above the sea and is surrounded by high mountains. There is a gentle slope from the sides to the centre and the main drainage line is westward. Surface drainage is therefore easy.

Rainfall. The total rainfall is low, about 10·5 inches a year. Most of the precipitation takes place during the winter months, December to March, often in the form of snow. The shallow, cold-weather depressions, which form over Persia and move down into North-West India, often pass over the Quetta valley, and, in doing so, deposit a portion of their moisture. It is to this cause that the winter rainfall in this tract

is principally due. The valley is outside the usual area of the Indian monsoon, but, it sometimes happens, that the storms which cross the continent from the Bay of Bengal, after depositing most of their moisture in Hindustan proper, break up among the valleys of Baluchistan. These increase the humidity of the air and give rise to showers of rain during the months of July and August, but the total quantity received is not great.

Besides the winter rain, there are three chief sources of water for agricultural purposes—*karezes*, artesian bores and subsoil water. The usual method of irrigation is by means of the *karez*. This is an underground ditch on sloping land, which collects the subterranean water near the hills and discharges it on to the surface. It is really an adit with a slight slope, driven into a fan talus with a much greater slope of 300 to 600 feet per mile. The land below the opening of the *karez* is watered by gravitation. The artesian bores as a rule are only about 100 to 200 feet deep and are of from three to four inches in diameter. The water comes from underground streams so that this method of supplementing the rainfall is largely a matter of luck. The depth of water in the wells varies a great deal. In the Civil Station at Quetta it is often less than ten feet, but on the higher land outside it varies from 20 to 30 feet. Little use is made of this water at present for irrigation purposes on account of the expense and trouble of lifting it. There is little doubt, however, that, in certain localities, this groundwater is made use of by trees.

Temperature. There is a well-marked winter at Quetta and, from November to March, the general temperatures are low. The summer months June, July and August are hot and, during this period, the minimum temperature is high. The mean temperature varies from 40° in January to 78° in July. The feature, however, of the climate is the great daily range of temperature and the fact that during the winter there is a good deal of air movement. The diurnal range varies from 21·8° in January to 32·7° in November.

Humidity. Except when the south winds blow in July and August or after rain, the humidity of the air is low, much lower than in many parts of the plains of India. The drying effect of the air is further aggravated by much air movement, often from the west. Evaporation is therefore rapid so that in fruit growing, devices for checking the effects of dry winds are necessary. Mud walls, wind breaks of growing trees and cover crops, which shade the ground, can be used for this purpose.

Soil. The soil varies from brown to black in colour and resembles the alluvium of the Indus valley in general appearance and texture.

The soil is a loess deposit, apparently formed by accumulations of wind-blown dust, sometimes mixed with alluvium. With such a geological history and in a climate of great aridity, there have been no opportunities for the accumulation of organic matter. It is not surprising therefore to find that stable manure and green-manuring in the Quetta valley lead to an immediate improvement in production. Most of the soil of the cultivated areas does not possess a great range in the size of the particles and behaves on wetting very much like the Gangetic alluvium. Flooding destroys the porosity and the surface easily runs together. Under the dry, hot winds, which are frequent at Quetta, irrigated land sets on the surface into a cement-like mass, which rapidly loses its moisture. There is a great response to aerating agencies such as heavy dressings of stable manure, the growth of a lucerne crop or green-manuring with *shaftal*. All these methods tend to reduce the evils which follow from surface flooding and act largely by promoting ventilation and giving the roots the needed supply of air.

2. Plant growth.

Most of the growth of trees takes place in the spring and early summer and, as at Pusa, growth slows down towards the end of June. As in the monsoon-fed areas of the alluvium, this falling off of growth is partly due to the destruction of the pore spaces in the soil which in turn interferes with the air supply to the roots. The agent which destroys the soil texture in this case is however not the monsoon but man himself, who insists on the frequent and copious flooding of the surface with irrigation water. This proceeding, in such a soil as that of Quetta, cuts off the air supply to the roots, growth stops and the trees begin to look unhealthy. This is often interpreted as a sign of want of water, so, more is applied with the result in many cases that growth stops entirely. Fortunately, the fall of the leaves in autumn puts an end to the application of water and during the frosts of winter some of the porosity of the soil is recovered. There is no doubt, however, that great damage is done by surface flooding at Quetta and that a great deal of valuable water is being wasted.

3. Some examples of soil ventilation.

During the preliminary work in connection with the establishment of the new Fruit Experiment Station at Quetta, several examples of aeration effects have been observed which are of general interest. Further, they indicate one of the chief directions in which the agriculture of the valley can be improved.

The yellowing of peach trees. As the summer progresses at Quetta, the foliage of the peach trees alters in colour and changes first to light green and finally to yellow. The last formed growth is chiefly affected and, after the yellowing stage has well set in, premature leaf-fall begins. By the end of August, many of the leaders are either quite bare of leaves or have only a few at the tip. In addition to the yellowing of the foliage, two other symptoms manifest themselves. The wood gives off large quantities of gum and the ripening fruit is deficient in flavour. Peach trees affected in this way die out in two or three years, the process taking place in stages by the death of one or two large branches at a time.

The yellowing of peach trees at Quetta is not universal. The best examples can be seen in the Civil Station, where the soil is somewhat heavy and close in texture. In the fruit gardens of the zamindars, which are either under lucerne or allowed to run to weeds, chiefly *busunduk* (*Sophora alopecuroides*), yellowing is much rarer and the peach trees are generally healthier.

On taking up the detailed examination of this yellowing in 1912, three possible causes appeared to be worth investigation. The trouble might be similar to the disease known as "peach yellows" in the United States, the yellowing might be due to a lack of available nitrogen in the soil or want of aeration of the roots might be the cause.

A comparison between the symptoms of the trouble at Quetta and the description of peach yellows published by the United States Department of Agriculture[1] showed that one of the characters of this American disease, namely, reddening and premature ripening of the fruit, is absent. Further, buds taken from normal and yellow trees gave rise to equally healthy plants. On the other hand, in the case of peach yellows, buds from diseased trees, when propagated, either do not take at all or else give rise to diseased plants. The yellowing of the peach trees at Quetta was therefore not "peach yellows."

As regards the possibility of want of available nitrogen in the soil, all the experiments made gave negative results. Dressings of both nitrate of soda and of sulphate of ammonia produced no effect.

Since 1912, a large amount of evidence has accumulated that the trouble is entirely due to a deficiency of air in the soil for the use of the roots and the yellowing of the peach and other trees at Quetta is a simple aeration effect. The evidence for this view can best be set out in order.

(*a*) The distribution of yellowing. The yellowing of peach trees is for the most part confined to areas where vegetables are grown between

[1] E. F. Smith, *Additional evidence on the communicability of peach yellows and peach rosette*, Washington, 1891.

the peach trees or where the soil is close in texture. In the growth of vegetables at Quetta, watering is very frequent and the subsoil is in a constantly moist condition. This frequent irrigation destroys the porosity of the soil and the air spaces are filled with water. The vegetables, being surface rooted, use up the air in the soil above the peach roots. The peach roots, under such circumstances, are deprived of oxygen and carbon dioxide accumulates in the lower soil as a result of the vegetable cultivation. The result of all this is seen in the yellowing of the foliage of the trees.

(*b*) Deep planting and over-irrigation. When young peach trees are planted too deeply, the foliage is always yellow and this yellowing develops as more water is applied to the trees as the summer progresses. Some cases of this occurred at the Fruit Experiment Station in 1914. Yellowing is also produced in the spring if the trees are too frequently watered. Some plots at the Experiment Station were purposely over-watered early in 1914 and, at the beginning of May, the yellowing was well developed. Irrigation was stopped and the soil right down to the roots was broken up. Healthy dark green foliage was at once produced.

(*c*) Natural aeration. One of the weeds in peach gardens at Quetta is a natural aerator. This is *busunduk*, a very common weed of cultivation in the valley which grows in wheat fields, among the peach trees and on road sides. It is often employed for green-manuring melons and is the chief weed in the summer on fallow land. This plant is provided with thick underground stems which burst open the subsoil in all directions. The shoots coming to the surface, also tend to let air into the ground. When this weed grows in fruit gardens, the peach trees are seldom yellow as the *busunduk* acts as an aerator and neutralises, to some extent, the evil effects of surface irrigation.

Another natural aerating agent, which acts like *busunduk*, is *shaftal* (*Trifolium resupinatum*). It has this advantage over *busunduk* that the crop yields a valuable fodder and the last cut can be dug in as a green-manure. The tap root of *shaftal* is deep and the numerous laterals break up the soil in all directions. A great deal of growth takes place on the winter rains, and when the crop is ploughed in at the end of June, the soil is aerated. The addition of organic matter to the soil also tends to increase its porosity and therefore the air supply to the roots of the peaches. The cultivation connected with the sowing and ploughing in of this crop does a great deal of good to peach trees and even old trees, with yellow foliage, start new growth and improve in a remarkable way.

Lucerne is another natural aerator and is much better for fruit trees than vegetables. The roots of this crop are long and they

break up the subsoil to great depths. There are, however, disadvantages attending this crop. To get the maximum amount of fodder, lucerne must be watered very frequently and to keep the surface of the ground open, manure ought to be applied every winter or spring. The frequent watering, although beneficial for the lucerne, is nevertheless too much for peaches and cases can be seen in and near Quetta where the peach trees are yellowing although surrounded by lucerne. Another disadvantage of lucerne is that, to get the full benefit of the crop for fodder purposes, it has to remain in the ground for five or six years and during this time no cultivation is possible.

(*d*) The yellow condition is not propagated by buds. That yellowing is not a true disease but an unhealthy condition is shown by the fact that buds, taken from such trees, produce healthy plants.

Fallowing. It is the custom at Quetta in wheat growing to fallow the land after this crop. This is particularly the case when this crop is grown under irrigation. When a crop of irrigated wheat is ripe in June, it is observed that the *busunduk* in the crop is very pale in colour and looks unhealthy. This is due to the fact that the copious surface flooding given to the wheat, under an ascending temperature and in the presence of drying west winds, packs the soil like cement and effectually cuts off the air supply to the roots. Another result of the destruction of the structure of the soil by irrigation is to be seen in the ripening of the wheat crop itself. Wheat does not ripen at Quetta but dries up, with the result that the grain is thin and not well filled. This always happens with wheat if the air supply to the roots is cut off before the ripening process is complete. The present methods of growing irrigated wheat at Quetta entail the loss of vast quantities of valuable water much of which can be saved. How this can be done will be shown in a subsequent paper. The net result of the present practice is to leave the soil so cemented together at harvest time that the robust *busunduk* is nearly asphyxiated. The baked soil becomes more porous after the winter, and during the fallow year following the appearance of the *busunduk* is very healthy. The large underground stems, which run like ropes parallel to the surface about a foot down in the soil, produce a large number of new vertical shoots and these force their way through the compacted soil. In this way, the texture of the soil is improved, the gaseous interchange with the atmosphere is renewed, and the soil is ready for a new crop. Thus the copious watering for wheat not only wastes water and prevents the crop ripening, but also puts the land out of cultivation for a whole year. But for the *busunduk*, the subsoil plough of the Quetta valley, and the frost, the present methods of growing wheat would ruin the land.

Surface crusts. Both in the gardens and in the field at Quetta, the surface crusts, formed by irrigation water or by rain, must be broken up if the best results are to be obtained. The breaking of the crust promotes aeration and also conserves the moisture in the soil underneath. The latter reason is well understood but the ventilation aspect is not always appreciated. In the case of wheat-growing at Quetta, a great deal can be done in water saving if the crusts, formed after the winter rains, are broken up when dry by lever harrows. These harrows can be drawn over young wheat in such a manner that the crusts are broken up and a dry surface mulch left without doing any harm to the crop. By their use nearly nineteen maunds of wheat per acre have been grown at Quetta on unmanured land, on a large scale, with only one irrigation before sowing. With a few obvious improvements, it will be possible to increase these yields and to grow almost as much wheat with one irrigation before sowing as by the six or seven irrigations now given. In addition to this saving of water, the *busunduk* will not suffer to so great an extent.

In this connection, some reference to the use of the harrow in dry farming operations generally is desirable. In the literature on this subject, the advantages of harrowing wheat are always put down to the saving of water caused by the mulch of dry soil brought up by the harrow. This is only partly true. A portion of the benefit of harrowing is due to the aeration of the roots of the wheat crop and to the promotion of gaseous interchange between the soil and the air which results from a loose mulch on the surface. It has often been seen at Pusa how much harm is done if heavy rain falls when the wheat is ripening and makes the mulch run together into a crust. The best wheat is always produced at Pusa when no rain falls after the wheat is in ear. Rain crusts can easily be broken in the early stages by harrowing, but after the ears appear this is no longer possible.

IV. SOME FURTHER INDIAN OBSERVATIONS.

I. Aeration in the black soils.

The Ganges and Jumna mark roughly the line of division between the alluvium and the soils of the Peninsula. As regards the method of aeration in the two classes of soil, nothing could be more distinct. As mentioned above, the alluvial soils have a great tendency to pack and run together and there is little or no natural aeration during the hot season. The black soils are quite different in this respect. They

expand during the monsoon into a jelly-like mass and begin to crack after drying. This goes on all through the cold season. Further contraction takes place during the hot months, and deep, wide cracks are formed in all directions. *Rabi* crops obtain an abundance of air by this process, and so great is the cracking, that moisture is lost and roots are broken. On this account, in wheat growing, varieties on the early side produce much the best samples, both as regards appearance, yield and quality. The cracking of these soils in the hot weather, combined with the hot winds, is a perfect aerating method. On such soils, hot weather cultivation, which is so necessary on the alluvium, is not likely to be worth the labour involved.

The expansion of the black soils during the monsoon, however, if long continued, might easily result in damage due to the air supply being cut off. Other things being equal, one would expect the best results with monsoon crops on these soils in years of moderate and well distributed rainfall, by which suitable relations between air and water in the soil would naturally arise.

In some tracts south of the Ganges, the tendency of the soils to crack after inundation is of great agricultural importance. At Bhagalpur, for example, the *deara* lands are flooded during the monsoon, nevertheless they bear good *rabi* crops. The aeration of the land is almost entirely brought about naturally by the property of these soils of contracting on drying and of forming cracks in all directions. The contrast between these *deara* lands and the low lands north of the Ganges in Tirhoot is most marked. After flood years in North Bihar, the porosity of the soil is destroyed, denitrification is set up and the *rabi* crops are poor. If the Bihar soils would crack on drying, the harm done by monsoon inundation would be reduced almost to half.

2. Edge effects on the alluvium.

Almost every European, who takes an interest in cultivation in the plains, notices the edge effect in his garden. When vegetables are grown under irrigation, the easiest method of applying water is to divide up the area into small beds (*kiaris*), each surrounded by a low embankment to contain the water. Water is led into these by means of a small canal running between the beds. The resulting growth is very uneven and the best vegetables are always seen round the edge of the bed. The explanation of this is at once evident when it is realized that the roots must breathe. The flooding destroys the porosity of the soil on the floor of the bed, partially cuts off the air supply to the roots and the growth is checked. The plants round the edge of the bed are in a different condition and towards the outside their

roots can obtain a good deal of air through the embankment. As a result, they grow strongly and well while those in the centre show all the signs of oxygen starvation. As the surface dries, the *mali* considers the plants require moisture, so more water is added and the air supply is still further interfered with. These evils can be largely got over by means of furrow irrigation.[1] By this means, water can be added without destroying the porosity of the soil.

3. The saving of irrigation water.

In all the irrigated tracts of the plains, the saving of irrigation water is one of the great problems which lies before the Agricultural Department. In well-irrigation, the less the water used per unit area, the more the cattle can be employed for other work or the greater is the area that can be watered. In the canal irrigated areas, any saving of water means a larger area commanded and therefore a greater revenue to Government and a greater density of population. This is, however, only a small part of the case. Surface flooding, in many parts of the Indo-Gangetic plain, is exceedingly harmful to the crops, as it tends to prevent the aeration of the roots of the plants and to diminish the yield. The chief problem now before the Agricultural Department is to show how, under an irrigation system on a fine alluvium, the proper relations between air and water in the soil can best be maintained. Once this is done, water saving will follow as a matter of course. The cultivator will then discontinue his present practice of poisoning his crops by means of water. The solution of this problem is not a difficult matter provided it is approached from the point of view of the plant. In the case of a crop like wheat for example, grown in the Canal Colonies, three or four heavy waterings are now required to ripen the wheat. One is applied before sowing and the rest afterwards. By the selection of suitable early varieties and later sowing, it would be easily possible by two waterings at the most, one applied before sowing and the other later, to raise crops at least as large as those now grown. After the second irrigation, the surface would have to be well broken up by lever harrows to leave a mulch to conserve the water and also to aerate the roots. Similarly in the United Provinces, a great saving of water in wheat growing is practicable. Some progress has already been made possible by the provision of the variety Pusa 12, which ripens excellent crops with less water than late sorts like Muzaffarnagar. At Quetta, nearly nineteen maunds of wheat to the acre have been grown on one

[1] Howard and Howard, *Mem. of the Dept. of Agr. in India* (*Botanical Series*), Vol. III, No. 1, 1910.

irrigation in place of six or seven now given. This is only the beginning but the results already obtained show what is easily possible in the future if this line of work is taken up in the right way.

The evil effects of surface flooding in the Indo-Gangetic plain vary according to the physical constitution of the soil. In the Province of Agra, the alluvium is generally more open and sandier in texture than in other parts of the plains such as the Canal Colonies of the Punjab or the middle Doab of the United Provinces. On the somewhat sandy soils in the Meerut Division, gram is irrigated with advantage while three waterings for wheat give heavy crops of well-ripened grain.[1] Both these results are largely aeration effects and are only possible because surface flooding, in this case, does not destroy the porosity of the soil and cut off the air supply. In the Canal Colonies, on the other hand, gram does not, as a rule, thrive well under canal irrigation and the last watering often damages the wheat sample. Here the texture of the soil is closer and surface flooding interferes with soil aeration. While surface flooding is not particularly harmful in the open soils of the Meerut Division, there are however other directions in which canal irrigation is harmful. In this tract, there is a large amount of seepage from the canals and large distributaries and damage accordingly results to the neighbouring country. In such cases where the surface can be flooded with impunity, seepage becomes a danger and it might easily pay to line the canals in the first instance in such tracts. The capital cost would be increased but a great saving of water would result and the damage done by seepage would be lessened.

The famous vegetable soils of Lucknow are another instance where the surface can be flooded without any great harm. Here the soil is very sandy and the *kiari* effect is not seen. Provided these soils are well-manured, splendid crops of tobacco, vegetables and cold weather annuals can be grown with surface flooding. The result depends on the natural aeration which takes place in these soils and this explains the excellence of the vegetables and flower seeds grown at Lucknow. When the Horticultural Gardens are supplied with a proper amount of irrigation water, it will be possible to grow there the vast quantities of the seed of cold weather vegetables and flowers which are now imported at great cost from England and Germany.

[1] The fact that high yields of well-filled, white wheat are produced in the Western Districts of the United Provinces has drawn attention to the wheats of this tract and attempts have been made to spread the wheats of the Muzaffarnagar District to other areas. In the majority of cases, these experiments have not proved very successful. The sample of wheat produced in the Meerut Division is probably due more to the fact that the aeration of the soil is not destroyed by surface flooding than to any inherent excellence in the varieties grown.

V. SUMMARY.

In the foregoing, many examples have been given which prove that one of the conditions for the growth of crops is an ample supply of air for the roots. At the same time, many directions of progress in crop production on the Indo-Gangetic alluvium and in the Quetta valley have been suggested. Incidentally, the basis of the saving of irrigation water has been indicated.

One further point remains, namely, that of the distribution of crops or the ecological aspect of agriculture. Crops undoubtedly differ greatly in the amount of air their roots require. Gram, for example, requires a great deal of air and only a moderate amount of water. This is proved by the present geographical distribution of this crop in India. It is most widely grown in the Agra Division, in the *barani* tracts of the Eastern Punjab and in Central India. In all these places, the soil and the system of cultivation are such that its roots get plenty of air. In the East of the United Provinces, in Bihar and in the canal irrigated areas of the Punjab, gram is not so common and, in these tracts, the literature on this crop abounds in references to the precarious nature of the yield. In these areas, the air supply of the roots and of the nodules is often interfered with by water in the soil. That this is so has been proved at Pusa where, on high, light, well-drained land, excellent crops have been produced while on heavier land, not fifty yards away, the crop, although promising in the early stages, has not yielded the seed sown. The proper provision of air to the soil is all that is necessary for extending the cultivation of this most useful crop.

It may not be out of place here to suggest a further application of the ideas in this paper, namely, in the direction of ecological studies and in the distribution of forest trees. Aeration of the soil might easily prove to be a more important factor than the writings of Schimper and of his modern followers seem to indicate.

From the purely agricultural aspect, this paper has attempted to establish two principles, namely :—

1. To obtain the best crops in the alluvium, great attention must be paid to adjusting and maintaining the proper relations between air and water in the soil.

2. Water, when it excludes air from the roots, acts as if it were a poison to crops.

PUSA,
December 16th, 1914.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 53 1915

Agricultural Research Institute, Pusa

Soil Erosion and Surface Drainage

BY

ALBERT HOWARD, C.I.E., M.A.,

Imperial Economic Botanist

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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SURFACE DRAINAGE AT PUSA.

Soil Erosion and Surface Drainage.

I. Soil Erosion.

The whole of the cultivated area of India, affected by the monsoon, is subject, to a greater or less degree, to the loss of fine soil by rain-wash. Several factors are involved in this continuous erosion of the soil.

Perhaps the principal one is the uneven distribution of the rainfall. In much of the monsoon fed area of India, the rain, as is well known, is concentrated into a few months of the year. During this period, the precipitation is by no means evenly distributed, and, almost every year, one or more concentrated bursts of rain occur which often exceed six inches in a single day. The soil is frequently unable to absorb this heavy precipitation, with the consequence that the run-off speedily accumulates into a stream of water, heavily charged with fine particles of soil, which makes its way, either to streams, rivers or to low-lying land. On the way, the moving water removes more earth and in many cases, if this goes on unchecked, a small *nallah* is formed which year by year increases in depth.

The general slope of the ground is another factor which influences the rate of erosion. Where this is considerable, as in many parts of Peninsular India, the damage done by rain-wash is much more evident than in the flatter alluvial plains. In many parts of Bundelkhand and the Central Provinces for example, almost all the culturable soil has been washed away over large areas leaving the bare rock exposed. In the plains, beyond the ravines near the rivers, the evidences of erosion are not so obvious but nevertheless they exist if careful observations are made. It may be taken as a general principle that wherever storm water can move on the soils of India, erosion is constantly taking place.

The third factor on which the amount of erosion by rain-wash depends is the nature of the soil. On equal slopes exposed to the same rainfall, light, open soils lose more silt than heavier loams. Heavy, black cotton soils, which swell up when wetted, are probably not denuded so readily as the lighter soils found in Peninsular India.

In most cases, the soil removed by rain-wash represents a distinct loss to agriculture. Some of the soil is carried away by rivers and deposited, partly along their courses and partly in their deltaic regions. The remainder is carried to low-lying areas, such as rice lands, where it adds to the existing deep layers of fine soil. It is sometimes thought that the deposition of silt, both in deltaic regions and in low-lying rice lands, is absolutely necessary to keep up the fertility of these areas and to manure crops like paddy and jute. If this were true, the transference of some of the fine soil would not be a loss to India as a whole and would only be a movement of agricultural capital from the high-lying to the low-lying areas. There is, however, some evidence which indicates quite clearly that low-lying lands do not need further deposits of silt to maintain their fertility. The continuous wheat plot at Pusa, which is really drained rice land and which previously obtained annual accretions of silt by rain-wash from higher ground, has been cut off from these areas for the last seven years and has not received during this period any new deposits. There is no sign of any loss of fertility. The plot has received no manure and, as far as can be seen, the fertility is increasing rather than decreasing. It is highly probable that the benefits conferred on rice lands by flood water are not entirely due to the silt brought down by the water but are connected with the aeration of the roots of the crop. A rice field is after all only an example of water-culture on a large scale. Everyone who has grown plants in water-culture knows that, besides the nutrient salts, the plants will not thrive really well unless the water is aerated. The only way a low-lying rice field can get its soil water aerated is by a slow passage of fresh, oxygenated water past the roots. If the water remains stagnant, the rice crop, as is well known, does not thrive. This result is due to the fact that there is an insufficient supply of air for the roots of the rice. If, however, there is a slow flow of aerated water over the fields, the water round the roots gradually becomes changed and a new supply of air is thus made available for the plant. Harrison[1] has shown that a part of the

[1] Harrison and Aiyer, The gases of swamp rice soils. *Mem. Dept. of Agr. in India (Chemical Series)*, vol. III, no. 3, 1913, and vol. IV, no. 1, 1914.

oxygen required by the roots of swamp rice is produced by the algal film on the surface of such areas and that a very slow movement of water through the upper soil is necessary to carry the oxygen to the roots of the crop. His investigations have thus served to draw particular attention to the aeration of the roots of rice and there is little doubt that his work supplies the explanation of much of the benefit to this crop which follows successive inundations of river water which slowly flow over and through the rice areas. It is highly probable that filtered water, provided it is well aerated, would do almost as much good to rice in deltaic Bengal as silt-laden water. The real need of the rice crop seems to be the water which is essential in carrying a supply of oxygen to the roots of the plant. The silt deposited by this water is largely unnecessary and must therefore be regarded as almost entirely lost to the country.

The amount of the annual loss of soil in India through erosion by rain-wash is very considerable but the full extent of the damage is not always understood. The most obvious and striking examples are to be found south of the Jumna in Bundelkhand, in Central India and in parts of Bombay. In these tracts, the evils of denudation are being realized and, in certain areas, a good deal of valuable work has already been accomplished, often with the help of Government, in protecting the cultivated areas from scour by rain. That much still remains to be done in this direction will be clear from a perusal of the appended paper by Mr. H. Marsh, C.I.E. (formerly Consulting Engineer for Protective Irrigation Works, Central India), which was published in the *Agricultural Journal of India* in 1906. This is perhaps the best account that has yet been written of the evils which follow from erosion in Central India and of the means of protecting the soil of the country from further destruction. The paper is evidently the work of an experienced engineer and moreover of one possessing considerable agricultural insight. It deserves the closest possible study on the part of every Engineer and of every District Officer in the country.

The damage done by erosion in the past in Central India was referred to by Colonel Pitcher in his evidence before the Irrigation Commission of 1901-03 as follows:—

"In all three divisions or 'Prants,' named, respectively, Gwalior, Isagarh, and Malwa, and comprising 6 districts apiece, are to be found the remains of ancient irrigation works in the shape of *bunds*, partly earthen, partly masonry. This is particularly the case with Northern Gwalior where, in 1896 A.D., famine was most severe. In

the black soil tracts, remains of old works are fewer in number, but are sufficient to show that it was found at some time or other worth while to irrigate such soil. To 'Raja Man,' who flourished about 500 years ago, is always ascribed the construction of these works. It is certain, from remarks by Fry and other travellers, that in former times Gwalior was the centre of a higher class of cultivation than is now the case, and stone sugar mills or oil mills scattered all over the country, often grouped in one place in large numbers where neither cane nor oil-pressing is now carried on, evidence some remarkable change of circumstances which may reasonably be ascribed to the existing waste of storm waters as compared to the practice of ancient times. Not only have the districts become arid, but the enormous quantity of surface soil washed off annually carries away with it fertility, leaving to the cultivator the labour of re-creating a fertile seed-bed on the subsoil. What appears to be called for in Gwalior is the restoration of humidity to the atmosphere by creating reservoirs and large evaporating surfaces of water, and sites for such works abound."

Soil erosion is, however, by no means confined to Central India. In the great alluvial plains of Northern India, where, at first sight, the country seems quite flat, the amount of damage done by rain-wash is enormous. As in Central India, the loss of soil by denudation in the valleys of the Ganges and Jumna is only generally recognized when the erosion has proceeded far enough to cut up the country into deep ravines, which generally run back from the rivers or low-lying areas. While this ravine formation is the most obvious result of the scour, nevertheless it is likely that this form of damage is of far less importance than the slow removal of fine soil from all the high-lying portions of the plains. This form of erosion is not very obvious at first and can only be appreciated after constant observation of the run-off during periods of heavy monsoon rainfall.[1] The muddy water running down to the drainage lines is exceedingly rich in fine particles and this unchecked denudation has, in the course of years, brought about very definite results in the consistency of the soil. The upper lands have become open and sandy through the loss of fine particles, while the low lands have

[1] In the barren and uncultivated areas in Oudh, the rate of soil erosion during recent years can be estimated by the amount by which the roots of the large trees have been exposed by wash. In many cases, the large roots are entirely laid bare and more than a foot of soil has been carried away since the trees were planted. The small shrubs on these areas occur on small hillocks and now stand at a higher level than the general plain as they have protected the soil immediately beneath them by their foliage and also by their roots.

become stiff and heavy by the continued addition of new soil. The consequence is that high lands have lost to a great extent their power of retaining moisture and only yield good crops with the help of manure. The low-lying rice fields have received more and more silt and the thickness of stiff soil has increased without any corresponding benefit to these areas.

The extent to which erosion of the high lands is taking place in the Bihar alluvium will be realized from some measurements made in the Botanical Area at Pusa at the end of 1913. These were made on gently sloping plots which received their own rainfall only and which were slightly embanked to prevent loss of silt by rain-wash. In plot 1 of the Northern Trial Ground, which slopes from south to north and is 94 feet wide, the rise of the north edge amounted to 6·5 inches since 1909. Similarly, in plot 2 of the Pentagonal Field, which slopes from north to south and which is 194 feet wide, the south side has been raised 4·5 inches in the last four years. These plots show in the clearest possible manner how great is the transference of soil from high to low ground during the monsoon. Very good examples of the same process are to be seen on the large *zerats* round the indigo factories. Fortunes have been lost in this manner in the past but the damage has not been realized by the planters as the loss of fertility by erosion has been made up by copious dressings of indigo *seeth*.

One of the most striking examples of loss of soil in Northern India is to be seen in the *karewa* lands in the vale of Kashmir. The *karewas* are high-level terraces, of considerable breadth, on both sides of the valley and stand well above the general level of the plain through which the Jhelum river now flows. These upper terraces slope very gently from the foot hills to the edges where the descent to the river valley is quite abrupt. The *karewas* are exceedingly poor and grow small, miserable crops. All the fine soil is being continually washed away by rain and nothing is done to check the process. The result is that a vast amount of the agricultural capital of Kashmir is yearly running to waste.

It is in the planting areas of the East however, that the most striking examples of soil denudation are to be seen. In the hill tracts in the centre of Ceylon, an area which is now covered with tea estates, the original forest canopy was removed to make room for coffee which later gave place to tea. Little or no provision was made at the time to retain *in situ* the fine soil of the original forest and, in consequence, the loss of soil has been enormous and is still going on. The water retaining power and fertility of the tea soils

of the hill regions of Ceylon have fallen off on account of the loss of fine particles and large sums are spent annually in adding green and other manures to the land. The agricultural capital of the Island has been allowed to run to waste and can never be replaced by any system of manuring. This short-sightedness is remarkable considering the local examples of terracing for rice on the slopes of the valleys where the preservation of the soil has been carried to a fine art.[1] There is no doubt that the best way in which the planting industry of Ceylon could have been assisted would have been by the enforcement of a regulation to terrace immediately all lands from which the forest canopy had been removed. I have heard that such a regulation is in force in Java. I am not familiar with the local conditions of the planting industries in the Federated Malay States, in Assam, and in Southern India, but I understand that in several of these tracts such as the Malay States, Southern India and the Darjeeling tea tract, this question of rain-wash is one of the greatest importance. It is difficult of course to remedy the mistakes of the past by any measures open to Government, but it seems to be a matter for consideration whether something cannot be done in the future in India where forest land is sold for planting purposes. The difficulty will be to frame rules with regard to terracing which, while allowing of the development of the country, nevertheless check the destruction of the natural agricultural capital, namely, the fine soil, rich in organic matter, made by the forest. The aim should be to allow the development of the country to go on but to prevent the dissipation of its natural resources. The example of Ceylon is sufficient to indicate the damage which results in these matters from the absence of a strong, guiding hand.

A consideration of the above examples of erosion in India leaves no doubt that the natural agricultural capital of the country, the soil, is slowly running to waste. This loss of fertility reacts on crop production and therefore on the well-being of the people. This impoverishment means debt, increased liability to diseases like malaria and finally rural depopulation. The gradual denudation of the soil of the country is the real "economic drain" in India. A little consideration must show that the first condition of improving crop production in India is to take steps to stop this constant erosion and to keep the cultivated soil in its place. Unless denudation is stopped and the fine soil is retained, it is clear that the provision of improved varieties of crops, of irrigation facilities, of improved credit, of better cattle and implements will not yield their full results.

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[1] See H. W. Cave, *The Book of Ceylon*, London, 1908.

II. Water-Logging.

In India, water-logging is often associated with soil erosion. When land has to deal with water, either as direct rainfall or in the form of flow, at a greater rate than it can be absorbed readily, the destruction of the porosity of the soil follows in the majority of cases. This is particularly so in fine, silt-like soils where most of the particles are very small and where there is no great range in diameter. Many of the soils of the Indo-Gangetic plain belong to the category of silt-like soils and are particularly liable to the destruction of their porosity by heavy rainfall or surface flooding. The pore spaces of the soil become filled with water, air is expelled and the particles slip into a position of closer packing. Such a condition is frequently produced during heavy falls when, in addition to the direct precipitation, the surface drainage from higher lands runs over the country towards the rivers or low-lying areas.

The degree to which water-logging takes place in India varies greatly. Every gradation is to be seen from slight damage to a crop to the production of saline efflorescence and the formation of permanent, stagnant swamps in which no cultivation at all is possible beyond a little precarious rice growing near the edge. The occurrence of slight water-logging can only be detected by a trained observer, who has learnt how to read his practice in the plant. The production of swamps, on the other hand, is of course obvious to all, but between these two extremes a vast amount of damage to crop production is being done every year which is only very dimly understood at the present time.

One of the best methods of detecting the occurrence of water-logging is a close observation of the growing crop. One of the first things to be noticed, in cases where the porosity of the soil has been destroyed, is a slowing down in growth and the production of yellowish foliage. This is often exceedingly unhealthy in appearance, and, if the roots are entirely deprived of air, as is sometimes the case during the monsoon, a diseased condition, described as wilt, ensues and the plants finally die outright. Besides the poor growth, the yield of water-logged crops is naturally low and the produce poor in quality. The signs of water-logging, however, are by no means confined to the monsoon crops themselves. The best examples are perhaps to be seen in the succeeding *rabi* crop, even in cases where no rain has fallen during the whole of the cold season. Grown on land, the porosity of which has been destroyed by water for long periods during the monsoon, the succeeding *rabi* crops show all the

signs of water-logging. The foliage is thin and yellow, the growth poor and the root system badly developed and near the surface. Such crops never stand the advent of the hot season but dry up quickly, although there is abundant moisture in the subsoil. They starve in the midst of plenty, on account of the fact that they do not root deeply, and therefore cannot make use of the subsoil moisture. This result follows from the want of aeration in the subsoil of such water-logged lands and to the fact that the roots cannot breathe for want of a proper supply of oxygen gas.

The damage done to crops by water-logging seems to be due to two main causes—lack of aeration[1] and the destruction of nitrates. If the soil is not ventilated properly, a full supply of oxygen does not find its way into the ground for the use of the roots and soil organisms and the carbon dioxide, which is formed in the soil in large quantities, cannot escape into the atmosphere. The result is that crop production is limited—directly by the want of air and indirectly by the inhibiting effect of the accumulation of carbon dioxide. Besides these effects, water-logging, if continued for some time, leads to the destruction of available nitrogen in the soil.[2] In the Bihar alluvium, these substances are produced in abundance at the beginning of the monsoon, particularly if the land has been cultivated during the hot season and, in the absence of frequent water-logging and weeds, are always available for the succeeding *rabi* crops. Water-logging, however, destroys the available nitrogen as will be clear from an experiment made at Pusa in 1910. In that year, a plot was purposely water-logged during the month of September in order to compare its behaviour with normally managed land. Across the middle of the plots, a strip was manured with nitrate of soda just before sowing with wheat, the total amount added being four cwt. to the acre. At first, the water-logged area did best due to the abundant moisture but, after the tillering period, it rapidly fell behind the areas on either side. The nitrated strip, in the water-logging area, soon became well marked but was hardly distinguishable on the control plots on either side. The yields are given in the following plan, from which it will be seen that the effect of a month's water-logging was to reduce the yield of wheat by about 16 bushels to the acre.

[1] The subject of soil ventilation in India has been dealt with in detail in Bulletin No. 52, published during the present year.

[2] It must not be forgotten that the soils of India are most frequently water-logged during the monsoon when the temperature is high, when the soil organisms are active and need large quantities of oxygen. Any interference with the air-supply of the soil at this period will naturally produce the maximum amount of harm.

The result of water-logging wheat land at Pusa in 1910.

Normal cultivation.	Water-logged during September.	Normal cultivation.
34·45	15·55	29·14
SHADED AREA TREATED WITH 4 CWT NITRATE OF SODA PER ACRE. 35·92	25·17	26·53
34·45	15·55	29·14

The numbers in the plan are bushels per acre.

Examples of water-logging are numerous, not only on the soils of the great plains but also on those of Peninsular India. On the black cotton soils, certain varieties of cotton suffer from wilt during the monsoon and, in the succeeding *rabi*, the wheat crop often shows by its foliage and weak growth the result of previous water-logging. These effects are probably associated more with the nitrogen supply than with aeration of the roots, for, on these soils, extensive cracking takes place during the cold weather which must lead to very copious soil ventilation. The contrast between the poor vegetative appearance of the wheat crop, in parts of the Central Provinces, and that on well-drained lands in Bihar and other parts of the plains is extraordinary, and all the symptoms indicate that denitrification, during the monsoon phase, has taken place in the former case.

The clearest examples of water-logging are to be seen, however, in the Gangetic alluvium, both in the United Provinces and also in Bihar. In both these tracts, local unevennesses in the crops are very common. Any partial holding up of the surface drainage and any slight concavity of the fields, due to depressions or to the misuse of iron ploughs, lead to local water-logging, to loss of available nitrogen and to the destruction of the porosity of the subsoil. In the

succeeding wheat crop, these areas give rise to a weak growth with yellow foliage and poor yielding power.[1]

In Bihar, the evil effects of water-logging are perhaps more abundant than in any other part of India. The silt-laden sheet of water which, during periods of heavy rain, frequently creeps over the surface from the high to the low-lying areas, does far more harm by destroying the porosity of the soil and by producing denitrification than any benefits conferred by the newly deposited soil. This was very evident some years ago at Pusa and also on the Dholi estate. As soon, however, as the low-lying areas were protected from surface wash, a marvellous improvement began which has continued steadily since. Unfortunately, the whole of the low-lying lands in North Bihar cannot at present be protected by surface drainage. In years of flood, large areas of the country are inundated and the water does not subside for many days. The monsoon crops of the flooded areas are partly destroyed outright, while the damage done to the next *rabi* crop is enormous. Any method, by which the general drainage of North Bihar can be improved, would confer almost as much benefit on this tract as the most successful irrigation project has given to areas which were formerly desert.

Some of the irrigation schemes carried out in India have, unfortunately, resulted in a certain amount of damage by water-logging, particularly in the immediate neighbourhood of the main canals. In tracts like Amritsar and Saharanpur, percolation has raised the level of the subsoil water so near to the surface that crops can be grown either *barani* or at a small expense by lift irrigation from the wells. In some of the canals in the Western Districts of the United Provinces, the soil is so permeable and the loss of water so great that masonry linings of the main channels have become a matter worth consideration. In these Districts, the soils are somewhat sandy and flood irrigation does less damage to the porosity of the land than in soils like those of the Chenab Colony. This very circumstance, fortunate as it is to the cultivators, leads, however, to great loss of water by percolation through the main canals and to a good deal

[1] In some cases in India, both manurial and varietal experiments are influenced by the effects of water-logging. This is caused by unevenness in levels, due to the misuse of iron ploughs; by raised grass borders between the plots and by the want of facilities for surface drainage. Experiments carried out under such conditions give very variable results, the figures of one year contradicting those of the last. An inspection of the actual experiments during the vegetative period shows that a water-logging factor, which naturally varies with the season, is cutting across the whole scheme and is introducing an unknown quantity, obviously greater than any possible differences due to the varieties or to the manures.

of local water-logging. In all new canals in such soils, it would probably pay to increase the initial cost of the project by permanent linings and to recover the extra interest in the form of water saved and in the protection of the country on both sides of the canals from water-logging.

The system of irrigation, in some of the river deltas of Madras, by the construction of anicuts across the stream, leads, in some cases, to water-logging. In the Godavari delta, the rise of the water level and the flooding of the surface has led to soil conditions favourable to disease in the sugarcane crop and the old varieties have had to be replaced by more resistant kinds. Besides affecting the well-being of the crops, this irrigation has given rise to a general insanitary condition of the villages of this area, a matter which was referred to at the Third All-India Sanitary Conference held at Lucknow in 1914.[1]

Some remarkable results in Bengal, which can probably be explained by water-logging, have been published recently by Dr. Bentley.[2] This investigator states that—

"In the deltaic areas of Bengal, still subject to inundation by silt bearing river water, malaria exists to so slight an extent as to be almost negligible and deltaic areas, which have been deprived of natural fertilizing inundations, have become malarious and unhealthy."

* * * * *

"The areas of intense malaria correspond, in a remarkable manner, with the deltaic portions of the country which have been deprived of their yearly inundations of silt bearing water, either because of natural changes or as the result of an artificial embanking of the rivers."

* * * * *

"Turning once more to Central and West Bengal, we may note that the greater portion of Nadia, Murshidabad, Hooghly and Burdwan have been deprived of the natural inundations to which they were once subject, by the construction of river embankments. In the old days, 50 or 60 years ago, these embankments were kept

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[1] M. Ramchandra Rao, Drainage and Sanitation in Rural areas in the Madras Presidency, *Supplement to the Indian Journal of Medical Research*, vol. II, 1914, p. 103.

[2] Bentley, *Supplement to the Indian Journal of Medical Research*, vol. I, 1914, p. 47.

in such bad repair that they did not prevent flooding of the country, and their harmful effect was not apparent. But shortly after they were made really efficient barriers to the inundation, the protected areas began to suffer in various ways. The fertility of the soil has been diminished, population has declined, and malaria has increased to an appalling extent.

A study of the conditions appears to show that the only effective way of combating malaria in these areas is to encourage agriculture, and bring once more under regular cultivation the areas of waste and fallow which are no longer cropped. But to bring this about it is essential that the fertility of the soil should be restored and this can only be done either by the use of manures or the utilization of river silt.

That some such measure as flood or basin irrigation would achieve this result, appears likely judging by the effect of the recent floods in the Burdwan District—where many areas have benefited by increased crops and lessened fever."

Dr. Bentley is no doubt correct in his main contention that the incidence of malaria in lower Bengal depends on the well-being of the people and is closely connected with the extent to which the rice lands are inundated with fresh river water. The silt, however, probably plays a subordinate part, and, as pointed out above (p. 2), the real value of the inundation is in aerating the roots of the rice crop. Where this inundation has been prevented by embankments, as in parts of the Burdwan District, there is no means of changing the water round the roots of the rice sufficiently. The crops behave like those in stagnant water; production falls off and with it the resistance of the people to the inroads of malaria. The interference with the well-being of the rice plant in all probability placed the unfortunate ryot in a vicious circle, the result of which has been, according to Dr. Bentley, partial rural depopulation. It will no doubt be possible in these fever-stricken areas to mitigate malaria by regulating the extent of inundation and so giving indirectly the roots of the rice crop the necessary supply of oxygen. The results of embankment in lower Bengal show how necessary it is to make no alteration in the natural drainage of the country without first of all considering the needs of the crops. If the wants of the crops are provided for, no damage is likely to result. If, however, as in some of the dry areas, where water-logging is produced by canals, and in the deltas, where in constructing embankments to check floods, the needs of the rice plant are forgotten, serious damage to the country is bound to result in the long run.

Up to this point in the present paper, an attempt has been made to indicate the damage to India which is taking place by unrestricted erosion of the soil by rain-wash. In the first place, large quantities of the real agricultural capital of the country, the soil, are yearly being removed and to a great extent lost. In the second place, this erosion leads to water-logging which in turn, by destroying the porosity of the soil and causing denitrification, leads to further damage. Water-logging is also caused by canal irrigation, particularly in areas where the main distributaries have to be carried across permeable soils and also in the anicut method of irrigation in the Madras deltas. Lastly, the protective river embankments in deltaic Bengal, which are said to be associated with the prevalence of malaria, appear to interfere with the aeration of the roots of the rice, with the yield of this crop and, in consequence, with the well-being of the people. Having indicated the nature of the general problem of erosion as it affects Indian agriculture as a whole, it now remains to deal with the remedies which are within the means both of the people and of Government.

III. Methods of Preventing Erosion and Water-Logging.

The evils which result in India from the erosion of the soil and from water-logging can very largely be prevented. Both erosion and water-logging take place because the run-off is not checked and because it is permitted to gather strength and velocity on its way to the drainage lines. Obviously, the principle to follow is to put the monsoon into harness and to deal with it on the principle of *divide and rule*. In this task, it will be an advantage if the monsoon is received on a well and deeply-cultivated surface, so that the maximum proportion of the early rains are absorbed into the thirsty soil. Many of the soils of the Peninsula crack to such an extent in the hot weather that an ideal absorbing surface is naturally produced. In the Indo-Gangetic alluvium, however, this is not the case and here it is essential to cultivate all vacant lands deeply and well during the preceding hot season. The absorbing power of such a surface is very great, and, during the early rains, there is no run-off and consequently no erosion and no water-logging.

Two inexpensive methods of harnessing the monsoon are dealt with in this section—embankments[1] and surface drainage.

[1] The principles of the methods indicated in this section are very similar to those in use in Italy at the present time in the operations known as *colmate di monte*. An interesting account of the Italian work is to be found in the papers of Sir Edward Buck and of Messrs. Hutton and Clayton in vol. II of the *Supplement to the Indian Journal of Medical Research*, 1914.

Embankments.

The successful utilization of embankments for the prevention of erosion depends partly on the nature of the soil as well as on the slope of the surface. Keeping the land under water for a long period naturally forces most of the air out of the soil. Unless the subsoil can afterwards be aerated sufficiently for a *rabi* crop, it is obvious that the plants will not get enough air for their roots and therefore will not thrive. Embankment therefore will have little chance of success for succeeding *rabi* crops unless the subsoil can be aerated afterwards. As is well known, many of the soils of Peninsular India contract rapidly on drying and crack in all directions and to great depths. This cracking means copious aeration and this occurrence renders possible the method of embanking on many of the soils south of the Ganges and Jumna. The alluvial soils of the Gangetic plain, on the other hand, do not crack to any great extent after being submerged and these soils dry very slowly. There is little or no natural aeration under such circumstances, and this fact probably explains why embanking for *rabi* crops on the Central India method is not practised to any extent on the alluvium.

The literature on embankments in Peninsular India is considerable. The subject has been ably dealt with by Mr. Marsh (see Appendix, p. 25) and the extent of the practice in the various Districts is dealt with in the *Agricultural Ledger* (No. 2, 1897) and also in the *Report of the Indian Irrigation Commission*, 1901-03. Several writers have dealt with the close connection which exists between embankments and the supply of water in the wells between two monsoons. There seems no doubt that, in sloping country, if the surplus rain flows off unchecked, the water has insufficient time to percolate into the subsoil and to reinforce the ground water. Unchecked erosion in such localities leads therefore to another source of loss, namely, to all the disadvantages which follow from a low and precarious water level in the wells. Not only is the supply of the drinking water affected but the labour of lifting water for irrigation purposes is increased.

There are two weak points in the system of field embankments in Peninsular India which are of some importance. Although in many places where the soil is deep, where the slope of the ground is comparatively small and where people are energetic, embanking is a common practice and much good results, nevertheless there is hardly any provision for the discharge of the surplus water. The whole of the rain is often held up and the fields become shallow

ponds. This is a disadvantage in two ways. In the first place, to hold a large volume of water for a long time, even where the slope is small, the bunds have to be made very strong and one or two breaches in a series might easily lead to very general damage to the whole and to the escape of a large volume of water, which would take with it much valuable soil. Where the slope is considerable, these difficulties increase and sudden heavy falls would be almost certain to break a whole series of embankments. The second disadvantage of the existing system is the practical certainty that the flooding of the land for long periods must lead to denitrification and consequently to diminished *rabi* crops. The wheat crop in many parts of the Central Provinces certainly looks as if it is suffering from a lack of available nitrogen and the whole subject seems well worth investigation from this point of view.

The disadvantages of embanking do not appear to be insurmountable. If the bunds could be combined with a suitable drainage system, by which the clear surplus water is run off, all the advantages connected with the prevention of erosion and with abundant percolation into the subsoil would be obtained while denitrification would be checked. Such a drainage system would only be possible, on sloping ground, by the provision of permanent stone falls or concrete pipes such as are in use in Italy. The people are unlikely to devise such a system themselves and would, in the first instance, at any rate, need the help of an engineer. Indeed the whole problem of raising the present method of field embankments in Central India from its present primitive condition to the dignity of a drainage system, comparable with Italian practice, is largely an engineering matter, and moreover is one which will call for considerable experience of local conditions as well as technical knowledge. Amateur efforts would, in many cases, only end in failure and disappointment which in turn would probably prejudice the consideration of well-thought-out projects in the future. One point would have to be allowed for, namely, the occasional use of flooding in the eradication of *kans* grass. This, however, would easily be possible by the simple process of stopping drainage in any particular unit of a series of fields.

Besides the question of construction, the combination of embankments with drainage presents other difficulties. These relate to land tenure, to maintenance and to supervision. It will at once be objected that methods which are possible on large estates in Italy do not apply to a country of small cultivators and zemindars, impressed with the importance of their own rights. The answer to

these objections would appear to be somewhat as follows. The small cultivator is after all a person of a somewhat limited point of view who is not likely to appreciate the value of any change except by actual demonstration. If it can be shown, by a few well-chosen and well-executed examples, that the present system of embankments can be improved and that the enhanced production more than pays the cost, a drainage project will stand on a somewhat similar footing to that of a canal or tank. It is more than likely that a demand would arise for small drainage projects and that they would be appreciated as much as a supply of irrigation water. That there exists in Peninsular India a vast field for experiment and for the application of engineering knowledge to agriculture seems undoubted.

The Pusa system of surface drainage.

A drainage system, suitable for the Gangetic alluvium, which at the same time prevents soil erosion, has been worked out during the last few years at Pusa[1] and is now being adopted on the indigo estates in Bihar. The small differences in level which occur in this tract make masonry falls for carrying off drainage water unnecessary, except in very rare cases and turfed channels are all that is necessary in this system. The method consists in dividing up the country into areas of from five to ten acres and surrounding these with trenches, the borders and sides of which are turfed to prevent cutting. The field trenches communicate with larger channels which carry the run-off either to low-lying rice areas or to streams and rivers. The size of the field trenches will vary according to the amount and distribution of the rainfall. In Bihar, it has been found that channels, four feet broad at the top, two at the bottom and eighteen inches deep, suffice in most cases. A grass strip, about a foot wide, should be left on the field on each edge of the trench to prevent breaching by the run-off and it is an advantage to let the grass grow on the sloping sides as well. The roots consolidate the soil and, after the first year, there is little trouble from breaches. A good deal of attention is necessary during the first monsoon in repairing the edges and in checking cutting. It is best to dig the trenches in the hot weather and to plant the sides and edges with *dub* grass on the early rains. During the monsoon, the trenches silt up to some extent and it is necessary to clean them out every hot weather, the soil being

[1] See *Agr. Jour. of India.* vol. IX, p. 197, 1914; *Supplement to the Indian Journal of Medical Research,* vol. I, 1914, p. 36; *Pusa Bulletin 33*, 1913, and *Quarterly Journal of the Indian Tea Association*, p. 24, 1914.

placed on the down side. A trimming up after the monsoon also adds to the general appearance of the fields. The arrangement of trenches is seen in the frontispiece, the photograph of which was taken in 1913. Since that time, it has been found an advantage to turf the sloping sides of the ditches as well as the borders next to the field.

By this method each field deals with its own rainfall only and water-logging is prevented. The border on the lower edge of the field becomes raised by the growth of the grass an inch or two above the level of the land and by this means a large quantity of the silt is deposited before the surplus water runs off. Some actual measurements of silt deposited on the plots at Pusa are given above (p. 5). The grass borders continue to raise themselves automatically as silt becomes deposited on the lower portions of the fields. Any small depressions in the plots soon become filled up with silt and areas surface-drained in this manner soon assume an exceedingly even appearance. The aim of the method is to keep the fine silt on the land, a matter which was referred to at the recent Sanitary Conference at Lucknow by the Hon'ble Mr. Hutton,[1] Chief Engineer and Irrigation Secretary to the Government of the United Provinces, in the following words:—

"I am firmly convinced that the problem to be solved in many parts of these Provinces and over a considerable part of India is not that of capturing the silt after it has found its way into our torrents and rivers but *to prevent it getting there.*"

In carrying out the Pusa system in practice, a drainage map is essential. This can best be obtained by following the method originally devised by Sir Edward Buck[2] in 1870 when Settlement Officer in the Farrukhabad District. This consists in marking on an ordinary map the direction in which rain water runs off the land. This enables the drainage lines to be determined far more easily and cheaply than by any system of taking levels. Once the drainage lines are known, the drains can be laid out to the best advantage, both from the point of view of the prevention of erosion as well as from that of surface drainage. Where the slope is considerable, the cross drains must run parallel to the contour lines and somewhat close together. The fields then become long strips.

[1] Report on the Utilization of Silt in Italy, *Supplement to the Indian Journal of Medical Research*, vol. II, 1914, p. 79.

[2] See Sir Edward Buck's evidence before the Indian Irrigation Commission, 1901—03, Appendix, p. 286, and the Proceedings of the Third All-India Sanitary Conference held at Lucknow in 1914 where the need of drainage maps in India was again brought forward.

These drainage maps have been in use for some time in the Irrigation Department of the United Provinces and are said to be more useful in laying out canal distributaries than any professional level maps.

The Pusa method of drainage has been found of the greatest use in the Botanical Area at Pusa in connection with the plant-breeding and other work. The disturbing influence, which water-logging introduces into so many of the varietal trials in India, has been removed and it has been found possible to take up such studies as the inheritance of quantitative characters in a sensitive crop like tobacco. The system is now being rapidly taken up on the indigo estates in Bihar with most promising results. Two years ago, a beginning was made on the Dholi estate and, in 1914, the system was greatly extended. The Manager of the estate (Mr. E. C. Danby), in a letter, dated 16th November 1914, reports on the results as follows:—

"I have now some 500 bighas at Dholi and my outwork, Birowlie, drained by surface drains on the Pusa system.

The improvement on all the lands is very marked, especially at Dholi where most of the lands are on a slope and the high lands suffered from loss of soil from rain-wash and the lower lands used to be water-logged at the time when they should be cultivated for *rabi* and indigo crops.

The advantage derived from the drainage is most marked in the low-lying lands which were formerly my poorest lands and these last year gave me as good or better returns of wheat and indigo than the high lands; and I am certain will still further improve. These lands I am now able to keep cultivated through the rains and to sow them at the same time as the higher lands."

Many other indigo estates are now taking up surface drainage and it is anticipated that it will soon be a feature of all the well-conducted indigo estates in Bihar. One of the most satisfactory results of the system has been the immediate recognition on the part of the ryots of the increased cropping power of drained lands. On the Dholi estate, several areas which previously could not be let to tenants at all and which had to be put under cheap crops like oats were, after drainage, immediately let out at high rents to tenants for the growth of chillies and tobacco.[1] The tenants have not regretted their bargain and these drained fields, which previously were either water-logged or eroded by rain-wash, are now giving splendid crops. Similar experiences have been reported

[1] In 1914 one of these drained areas under chillies was let for ninety rupees a bigha, another under tobacco for one hundred and forty rupees a bigha.

from other indigo estates such as Dowlutpore. The people are prepared to take drained lands at higher rents, a fact which promises well for the development of drainage schemes in Bihar. Round the Jeetwarpore estate near Samastipur, Mr. Dalrymple Hay reports, in a letter, dated February 4th, 1915:—

"I have been going in for your drainage scheme and find it very paying and to give proof that it is sound, some of natives are doing it on their own lands, after seeing the good results from what I have done."

Advantages of surface drainage.

The systematic drainage of indigo estates has been found to confer many advantages. Soil erosion is checked and the evils which result from water-logging are avoided. The division of the land into five acre blocks, surrounded by trenches, is found to be very convenient in practice.[1] The area of the numbered fields is known with accuracy, the records connected with cropping, rotation and manuring are easily kept, the renting of land to the ryots is facilitated, the trenches can be used for carrying irrigation water about the estate in the cold weather and the grass borders serve as paths.

In the work connected with the management of monsoon fallows for tobacco and *rabi* crops, drainage has been found to be of great assistance, particularly when combined with hot weather cultivation. One of the great difficulties in such work, in years of normal rainfall, is to keep the lands clean without too great an expenditure of bullock power and to get the cultivation done in the breaks of the rains. By controlling the run-off and allowing each field to deal with its own rainfall only, it is found in practice that cultivation can be carried out by means of the five tine spring-tooth cultivator at a very rapid rate and that weeds can be kept under even in very wet years. Advantage can be taken even of a short break to get over all the area, whereas without drainage, hardly any of the land can be touched. Equal advantages are obtained at sowing time, particularly after the *hathia*, when timely sowings are most important. The high lands dry very quickly and the low lands can be sown before the end of October. Besides controlling the rainfall, drainage enables an estate manager to be largely independent of the season. In addition to years of normal

[1] The difficulty in moving reapers and carts over the trenches can be got over by means of a wooden platform, on a pair of small wheels (placed under the centre), which can be drawn about by a pair of cattle. When put in position over a drain, the wheels hang in the air and the platform remains level with the ground on either side.

rainfall, when the run-off has to be got rid of, Bihar sometimes suffers from a shortage of rain. The Pusa system of drainage is found to be of great use in such years. When the land is well broken up during the hot weather, all the early showers are absorbed and, if a shortage of rainfall is feared, the lower edges of the fields can be raised by throwing up a few plough furrows and all the water can be absorbed. There will be no run-off at all and the moisture can be preserved by a surface mulch produced by the spring-tine cultivator or with the lever-harrow. The best crops of wheat yet produced at Pusa have been grown by following this method in years when famine conditions had been declared in the country round.

In indigo cultivation, drainage is also proving of great assistance. It has been found that the well-being of the indigo crop depends to a large extent on the aeration of the root-nodules and on the air-supply in the soil. If the porosity of the soil is destroyed and the air spaces are filled with water, wilt[1] occurs and the plants die. It is found that the yield of indigo on low-lying land is increased by drainage, a result which is to be expected if the manufacture of the indican depends on the well-being of the root-nodules. In the extension of sugar-cane cultivation in Bihar, drainage will also prove of use and should certainly not be neglected.

Drainage, by increasing the depth of aeration in the soil, enables an estate to improve its rotation and to substitute valuable for cheap crops. To a great extent the value of the crops in Bihar depends on soil aeration. Deep rooting plants and those which need a good deal of air in the soil are, for the most part, valuable crops, while surface rooting plants like barley are cheap crops. Drainage enables rather low-lying lands to be put into such crops as wheat, *rahar*, Java indigo and even tobacco. A proper drainage system in Bihar will probably lead to a decreased production of surface rooted crops like barley and to an increase in the area under wheat. The present distribution of crops depends on soil aeration and the most valuable ones are always to be seen on the high lands, not because these lands are intrinsically the best, but because it is only on such areas that their roots can get a proper supply of air. The present distribution of *rahar* and tobacco illustrates this point very well. When the lower lands are properly drained and cultivated, it is quite likely that they will produce very heavy crops of tobacco, and so add greatly to the producing power of the country.

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[1] See Second Report on the Improvement of Indigo in Bihar, *Agr. Jour. of India*, vol. X, part 2, 1915.

The development of drainage in Bihar.

The importance of drainage in the economic development of North Bihar is very great and there is no doubt that the production of the whole country could be almost doubled by this means. Drainage is a fundamental matter in agriculture as on it depends both the aeration of the roots of crops and the activity of many useful soil bacteria. It is of no use applying manure to water-logged land or to attempt to spread improved varieties of crops under such conditions. At present, it is clear that a very large part of North Bihar is water-logged during the monsoon and that the land is partly ruined thereby for the succeeding *rabi* crops. Too much emphasis cannot be laid on this basic fact. The future of Bihar agriculture depends perhaps more on soil aeration than on anything else.

Many circumstances are favourable for the extension of a large drainage project, on scientific principles, in this area. The differences in levels are small so that much of the water can be carried in earth channels and very little masonry work will be required. Labour is cheap and abundant and most of the work can be done by the people themselves. It is important, however, to have, first of all, a working-plan of the whole area so that the surplus water can be disposed of to the best advantage. In years of short rainfall, all the run-off will be required for rice. In years of average and heavy rain, there will be too much for this purpose and a good deal will have to be got rid of direct into the rivers and streams. If a large number of independent and uncontrolled drainage schemes spring up, it will be very difficult later on to control them, whereas if proper working-plans are laid down in the first instance, it will be easy to get people to fit local schemes into the main project. There is, after all, only a small number of rivers of limited carrying power in this area. In a proper drainage project for this tract of country, all the drainage lines would have to share in the work and no one of them should be overloaded with water as might easily happen if drainage is carried out indiscriminately. The well-being of the rice crop is another argument for a complete drainage project. As stated above (p. 2), one of the first conditions for a good paddy crop is the provision of a proper supply of aerating water for the roots of this plant. Rice will not thrive well in stagnant water or in water in rapid motion. It loves very slow moving water. It would be an advantage therefore if much of the water now sent direct into the rivers could be passed slowly through rice

chaurs and the surplus finally discharged into rivers lower down. It might even be possible to connect up a whole series of *chaurs* and to pass much of the drainage water from the Nepal hills slowly through these rice areas to a point lower down and so relieve the rivers. The rice would benefit and besides a valuable weapon in flood prevention would be obtained.

The construction of a detailed drainage map of the area is the first step to be taken before the drainage of North Bihar can be considered as a whole in a scientific way. The rivers would have to be studied in detail and the possibility considered of increasing the drainage of the country by opening up some of the old river beds and converting them into additional drains. The drainage map would enable a complete project to be framed which would be of the greatest use both to the people, to the zamindars and to the indigo industry. To the administration, such a working-plan would be of the greatest value in many ways.

Another aspect of drainage in this tract has not been dealt with, namely, the use of power in water lifting. So far, the system has only been tried on rather high-lying lands where the run-off can be got rid of by gravitational flow. There is, however, a large area of the country under rice, the yield of which depends on the rainfall. The paddy crops are almost everywhere precarious and depend on the distribution of the rain. In years of flood, they are often destroyed altogether. When the *hathia* fails, the yield is poor and it is somewhat rare to have a really good rice crop over the whole of North Bihar. This is reflected in the low rents obtained for rice fields compared with the high rates which are readily paid for high-lying land. If some of the higher rice areas could be drained, they would go up at least twice in value and would produce very fine crops of wheat as is shown by the behaviour of the continuous wheat plot at Pusa. There seems to be an opening for large drainage schemes[1] in this part of India by which the surplus rainfall on these rice areas could be lifted to the drainage lines by powerful pumps of the Roturbo type, which are adapted to deal with muddy water. The amount of water that would have to be raised is not very great and the height to which it would have to be lifted is only a few feet. The drained regions would of course have to be cut off from higher lands by catchment canals and the lower ends of the area, near the pumps, would have to be excavated to form collecting tanks in

[1] Some years ago, some successful work in power drainage was carried out on Captain Chapman's estate in the Partabgarh District (*Agricultural Ledger*, no. 16, 1894).

which rice could be grown. In calculating the surface water to be got rid of, some measurements of the amount of standing water left after rain on cultivated rice land would have to be made.

A successful drainage scheme in North Bihar would lead to the extension of the work to other parts of the plains such as the Punjab, the United Provinces and parts of Bengal. These drainage schemes, properly planned, would do at least as much for these areas as canal irrigation has done in the desert areas of the Punjab.

IV. Drainage Maps and Working-Plans.

The amount of work required to check soil erosion over a country the size of India and to combine this with drainage is enormous. It is evident that such a work cannot be undertaken by the State and, it is equally clear, that the people could not do it unaided. Much, however, could be done by the State and the people working together. If the State could employ a few first class engineers to study the question in detail, to supervise the construction of drainage maps and to draw up working-plans, the way would be prepared and the energies of the people could then be directed into profitable channels.

Drainage maps. It would seem to be difficult to improve on Sir Edward Buck's method of constructing drainage maps and it is fortunate that this economical system is available. Whereever the country has been surveyed, the run-off could be marked on the map and the drainage lines determined.

The utility of such maps in India at the present time does not end with drainage schemes. They would prove of service in many other aspects of the economic development of the country. They could be made use of in laying out new roads and new railways. These projects must naturally conform with the general contour of the country, not only on account of the cost of construction and of damage by floods, but also on account of interference with the natural drainage. As is well known, when this is interfered with, *reh* often accumulates and the agricultural value of the affected land falls in consequence. Similarly, these drainage maps would be useful in irrigation works and indeed in the United Provinces they have been employed successfully for many years. Other uses suggest themselves, such as town-planning schemes, malarial studies and projects connected with rural sanitation. In the general administration of the country, good drainage maps, on a suitable scale, would be most valuable. All kinds of questions arise from time to

time which have to be settled by District officers and which involve the rights of others and the well-being of the country. Drainage maps in many cases would be of great help in deciding many problems relating to land, to water, to communications and to town-planning.

Working-plans. The services of competent engineers would naturally not stop at the construction of drainage maps. It is only a step from these to the drawing up of well thought out drainage projects for large areas of country. These could be split up into sections corresponding with the District or Sub-division and would thus be available for all drainage works undertaken in that administrative area. Many enterprising zamindars and co-operative societies might make use of these schemes, the execution of which would thus obtain all the official support possible. The working-plans would be invaluable in all famine relief work and in schemes relating to the improvement of rural sanitation. For the Agricultural Department, whose sole concern is the improvement of the production of the soil of India and whose district organization is bound to come more and more in contact with the people, both the detailed maps and the drainage working-plans would be invaluable. There would obviously be no point in opening new farms or conducting operations in water-logged tracts until the drainage of these areas had been taken in hand. The existence of maps and the working-plans would often enable a good Deputy Director of Agriculture to initiate many a minor drainage project and so pave the way for other agricultural improvements.

PUSA,

February 5th, 1915.

APPENDIX.

PROTECTIVE WORKS IN CENTRAL INDIA[1]

BY

H. MARSH, C.I.E.,

Consulting Engineer for Protective Irrigation Works, Central India.

"I am disposed to think that the most productive parts of the surface of Bundelkhand, like that of some of the districts of the Nerbudda territories, which repose upon the back of the sandstone of the Vindhya chain, is (*sic.*) fast flowing off to the sea through the great rivers which seem by degrees to extend the channels of their tributary stream into every man's field, to drain away its substance by degrees, for the benefit of those who may in some future age occupy the islands of their delta. I have often seen a valuable estate reduced in value to almost nothing in a few years by some new antennæ, if I may so call them, thrown out from the tributary streams of great rivers into their richest and deepest soils. Declivities are formed, the soil gets nothing from the cultivator but the mechanical aid of the plough, and the more its surface is ploughed and cross-ploughed, the more of its substance is washed away towards the Bay of Bengal in the Ganges, or the Gulf of Cambay in the Nerbudda. In the districts of the Nerbudda, we often see these black hornblende mortars, in which sugarcanes were once pressed by a happy peasantry, now standing upon a bare and barren surface of sandstone rock, twenty feet above the present surface of the culturable lands of the country."

Thus wrote Sleeman some seventy years ago about Bundelkhand. His remarks are still true, except where enlightened administrators have encouraged and assisted the people to check the denudation by the construction of embankments. Nothing strikes the observing traveller in Central India more than the depths of the great river channels, their tributaries and even the small rivulets that feed them. This physical character leads to disastrous effects in a country, specially prone to famine, which is gradually being depopulated. Not only do the deep rivers and

[1] Reprinted from the *Agricultural Journal of India*, vol. I, 1906.

their affluents carry off the good soil, as described by Sleeman, but they also lower the subsoil water level, so that wells dry up, and cause serious privations to man and beast. Yet the position is not at all irremediable, and in this article I propose to state some of the measures likely to effect practical improvements.

The peasants are quite aware of the value of arresting the rapid drainage from their fields, not only for the purpose of conserving moisture for sowing and maturing the spring crops, but also as an infallible method of improving the fertility of the soil itself. Here lies, therefore, a prime opportunity for the various rulers of Central India to encourage this industry by every means in their power. In some States, I believe, considerable progress is reported where rulers have guaranteed proprietary rights in land protected by embankments, and in others useful State loans have been made with the same object. In British Bundelkhand and the Central Provinces, active measures have been taken for the construction of scientific field embankments to immerse areas of about 20 or 30 acres, and these efforts are sure to meet with success, if not neglected. But such action cannot have the same great effect, as would be obtained if the majority of cultivators could be induced to protect their own fields.

Where an embankment is made which affects the interests of several individuals, but is too small for State management, difficulties are sure to arise about its maintenance. One man wants to cut the bank of his immersed field so as to commence ploughing for the spring crop, whereas another wants to retain the water for his rice plants. Then, again, there is often trouble about the injury to standing crops from the escaping water, whilst the necessary annual repair causes difficulty unless there is a strong village headman to arrange about these matters. Thus, although large embankments are of immense value and particularly so where there is an enterprising village headman, yet they do not have the same permanence as small banks made by a cultivator round his own field. The truth of this statement is rendered patent by the many neglected embankments found in Central India. As an example, I may quote a few lines from my own notes in 1905, regarding Makhoni village in Datia State:—" About 1893 a Soukar called Sibhu made a lot of bunds in Makhoni, and then died. The heavy rain of 1894 burst them, and they have never been repaired. I think they could be put right for very little. At present, however, the village is without an enterprising man like Sibhu, and apparently nothing will be done until he turns up. The eastern half of Kheri has got into the hands of a strong

Soukar, and there the bunds are in good order, and the wells are being worked with great effect."

Again, the following extracts from Mr. Impey's Settlement Report of the Jhansi District for 1893, show the immense value of small embankments:—"Though not exactly a source of irrigation, but rather a means of conserving the benefits derivable from rainfall, the system of field to field embankments, found especially in Moth and the north of Jhansi, may here be mentioned. It can scarcely be said ever to have received the attention it deserves, for it is unquestionably of extreme value in protecting land against both erosion and *kans*, it recommends itself to the people themselves more than any other ambitious schemes, and it has a direct fertilizing effect."

* * * * *

"Field embanking is the simplest of all matters. A small earthen 'bundh,' from 2 to 6 feet high, is thrown up along that side of a field, which is crossed by the drainage from the field. Flanks are added, if necessary; or if the slope be very inconsiderable, the field may be enclosed by bunds on all four sides. One or two feet of water can in this way be kept up until after the end of the rains, and the land is thoroughly soaked before the winter sowings. In some parts of Moth and the north of Jhansi, series of these small bunds are found all down prolonged drainage slopes, and the land over which they have effect increases in darkness and in fertility every year."

* * * * *

"The advantages of the system are numerous. The people are willing to throw up the embankments, and to take takavi for them. The rain water is retained for the ground on which it falls, instead of scouring into *nallahs;* and as the *nallahs* are deprived of their supplies, they lose their velocity and power of cutting back into the good land above them. The productive power of the land is increased, and *kans*,* where it exists, is drowned out."

I have consulted many skilled officers on the subject of this form of protection, who all agree that it is of the utmost value in tracts of good soil, but that the cost would not be recouped in areas of poor gravelly formations. Every one seems to think that

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* *Saccharum spontaneum.*

field embankments will repay the outlay on fairly good soils (locally known as *mar*, *kabar*, *parwa*, and the yellow *rakar*), but not in the case of such poor soil as red 'rakar' which is considered too porous. Still it seems a pity that the last named formation should be allowed to be denuded and I recommend the employment of State labour on such work in times of scarcity or famine. A great gain must be effected, if the water is compelled to enter the subterranean reservoirs instead of rushing along the surface, increasing storm discharges in the *nallahs* and carrying off more good land. On this matter, Mr. W. H. Moreland, Director of Agriculture, United Provinces, writes to me as follows:—"Turning now to the tracts where the soil consists of disintegrated rock more or less *in situ*, or South Bundelkhand as spoken of by your correspondents, I think myself they are inclined to underestimate the cumulative effect of retaining the finer soil particles, instead of letting them wash off. The soils being too coarse in texture to hold water to the best advantage, it is obvious that retention of the finest particles means gradual amelioration, as disintegration progresses; while to let them wash out, means no amelioration and possibly deterioration. But there is another consideration affecting the water supply in wells both for irrigation and for domestic purposes." Mr. Molony has gone closely into this point in his book on wells. I extract the following from his manuscript (now on its way to the printers):—"In the rock well tract, *i.e.*, parts of South Bundelkhand, Mirzapur, etc., the underlying rock has not the same capacity for storing water as the sandy subsoils of the Duab. Consequently, when a severe failure of the rain occurs, the evils of famine are often very much aggravated by a water-famine. The only thing that can be done is either to prevent the rain running off into the rivers by holding it on the land where it falls, or by taking the water out of the streams and pouring it on to the land lower down by means of canals."

* * * * *

"Another method is to make a number of small embankments or field embankments, each of which will hold up a little water. Even if such embankments hold up the water for a few days or hours only, they may be the means of saving quite a considerable portion of the rainfall."

Enough evidence has now been brought forward, to show what solid improvements can be effected, even in the small States where expert engineering assistance is seldom available. The Irrigation Commission were quite alive to the value of such work, and have

remarked:—"The practice of embanking fields has received considerable impetus during the recent years of drought; and we have no doubt that if immediate advantage be taken of the present feeling in its favour, a great deal of valuable protection can be afforded to the province at a small cost."

* * * * *

"More than one of our witnesses has stated that, on an average, embanking doubles the outturn."

"Again, two large embankments made in 1897, by Seth Nathu Ram, a Malguzar in the Saugor District, protected his village so effectively, that he not only kept his tenants on the land, but paid all his revenue in the year 1900, when his neighbours both lost many of their tenants, and failed to pay their assessment."

Turning now to a consideration of another form of protective work, I think that there is very fair scope for developing perennial irrigation in Central India by the construction of canals of moderate size. The Ken, Dassán, Betwa and Sindh rivers are all fed from extensive basins, covering several thousand square miles. Even in the driest years, these rivers pass off immense volumes of water, far more than would be necessary for all required irrigation, if there were only reservoirs to hold it. Then again the physical conformation of these drainage arteries is peculiarly fitted to the construction of magnificent storage sites. For centuries huge floods have been broadening and deepening the beds, with the apparent object of eventually breaking the rocky barriers over which the water has to leap at intervals. We have, therefore, numberless reservoirs already roughly fashioned out by nature, and the engineers have been left with the simple task of equipping the rocks with the necessary masonry and gates.

The experience of the Betwa canal has taught the Irrigation Department that no reliance should be placed on the cold weather discharges of a Central Indian river. Advantage must be taken of the absolutely certain monsoon floods with their numerous opportunities of storing water, until the necessary volume is secured. With this object in view, the reservoir at Paricha was increased by 50 per cent. in 1901, and in 1907 the capacity will be doubled by the construction of a new weir, already well advanced.

When this security has been reached, there is no doubt that the people will undertake the cultivation of sugarcane, early cotton and other valuable crops, and gradually approach the stage of comfort and affluence attained by the cultivators along the Jumna

and Ganges canals. It is easy to show that Government will also gain by its activity in the matter. The Betwa canal was opened in 1884, but though of great use as a protective work against famine, its revenue was less than its cost of maintenance until 1903, when the results of the extra storage began to be felt. During the twelve preceding years the average annual area equalled 37,000 acres, but it has steadily increased to 64,000 acres in 1902-03, 78,000 in 1903-04, 118,000 in 1904-05, and 162,000 acres in 1905-06.

These facts indicate the truth of a well known remark of Sir Thomas Higham, K.C.I.E., late Inspector-General of Irrigation, when he stated that to make a canal successful, money must be poured in as well as water. I am in great hopes, therefore, that surveys now in progress will prove that invaluable protective works are possible from the Sindh river, from the Upper Dassán and from the Upper Ken. When these projects are advanced, a move can be made to examine the remaining great rivers of Central India.

As regards lakes and isolated storage sites, there is no doubt a wide field for enterprise and unlimited work, but progress is bound to be slow, for a large establishment is required for observation and survey. But while the preparation of new schemes is in hand, much may be done in restoring old works, which are studded throughout the country. The causes of their failure are often due to mere neglect, but in many cases it is feared that the banks were cut with the expressed object of cultivating the rich soil in the beds of the tanks. This is a penny-wise and pound-foolish policy, as every drop of water should be conserved in Central India for the purposes of (*a*) strengthening the underground reservoirs; (*b*) creating dew, and reducing the aridity of the climate; and (*c*) increasing the comfort of man and beast. Moreover, the area gained by draining a tank is not so large as that which would be protected along the fringe of the water and below the embankment.

In the case of very old tanks, Mr. Sturt, late Assistant Commissioner of Jhansi, has noted that he considers their ruin to be due to the increase of flood water which now rushes down the *nallahs*. This increase he attributes to the denudation of the country, and he was of opinion that the same volumes did not exist in the Chaudal period, when water was jealously held up in every available spot and not allowed to accumulate into overwhelming floods.

Well irrigation is a splendid industry in Central India, but in a year of drought it is sad to see these sources of supply fail, when the crops are suffering, forcing the cultivators and their oxen to be idle. The fact is that well irrigation is not antagonistic, but is ultimately dependent on the forms of protection already dealt with, *i.e.*, field embankments, lakes, and tanks, riverweirs and canals. These three systems all tend to retain the water in the country and raise the spring level, which will no doubt bring back into use many an old well.

Regarding the effect of arresting the flow of rain water by the construction of lakes, it will interest readers to quote the exact words of Mr. Sturt, which were written more than thirty years ago:—"There is no questioning the fact that Bundelkhand was once a most flourishing province, supporting on its own productions a vast population, the extent of which it is now difficult to realise. There are numerous signs to prove beyond any doubt that extensive crops of sugarcane and other most valuable produce were raised in every part of the district with the help of well irrigation. Numerous old lakes, tanks, wells, and stone sugar-mills, which are found scattered about all over the district, testify to the fact, and are the monuments of the industry and science of the past ages. None but an immense community, such as we imagine the population to have been some ten centuries ago, could have undertaken the colossal works of that period, some of which still exist and defy decay. To the population and nature and extent of cultivation of that time, the existing condition of the district, and indeed the whole of Bundelkhand, can hold no comparison, and the difference is hardly credible. Taking Jhansi as a fair sample of the best of Bundelkhand, we find the proportion of the cultivated area to the area of the whole district 47·33 per cent. producing indifferent crops of all kinds and grain in quantities which are barely sufficient even for the support of the present scanty population, the average of which before the famine of 1868 was 203 souls per square mile. The *kharif* crops are extending, while the *rabi* which are more valuable, are proportionately diminishing (a certain sign of the poverty of the people) not so much from any paucity of plough cattle and cultivators, as from the loss of fertility of the soil, and loss of the means of irrigation. The former is attributable to the effect of surface drainage, and the latter to the fall of the spring levels of the country. This fact is most apparent to everyone who has lived in these parts and studied the subject. According to my idea the evils described above may be considered as the principal causes which have led to the present

reduced state of cultivation and poverty of the cultivating classes. And, as said before, these evils are the common result of the rapid flow and the scouring action of the surface drainage which, unchecked by artificial means, has worked its full destruction on the soil." On this point Colonel Corbett, after giving the proportion of the mineral particles contained in the rain water states regarding the *deterioration of the soil*:—" Hence the benefit of allowing rain to penetrate instead of allowing it to run off the surface, as in the latter case these mineral matters are lost to the soil, and not only are these lost, but also organic matters of all descriptions there may be on the surface; the minuter particles of the soil, for instance clay and lime, are washed out from between the coarser particles, which are mostly silicious sand. Thus the high land remains mere sandy soil." Colonel Corbett's experience, however, was that of the level countries of Rohilkhand and Oudh. If then, we find the wasting process of surface drainage so great in those parts, what must be its effects on undulating country like that of Bundelkhand? Many instances exist in which the land, which at the settlement had been recorded as *mar* and good class of *parwa* has now turned into *rakar* and *patro* respectively, and the cause of this is clearly traceable to the influence of "nallahs" and ravines subsequently formed, or increased in dimension since the settlement. Instances of the converse conditions also are present, in which the land has improved and changed from the inferior to the superior description, by damming up of streams and building up embankments round fields. Old temples, mosques, graves, wells and the like, built out in the open, show in a marked way the extent of wastage which has taken place on the surface of the ground; the very foundations of the old buildings are now exposed. The formations of the ravines are in themselves a convincing proof of this phenomenon, and if further facts are required, the field survey of 1835 may be compared with the lately made maps, and it will be seen that the most startling changes have occurred in the loss of culturable land and extension of barren plains and ravines. The culturable area decreases as the ravines and rivulets extend, which they are constantly doing, towards the watershed of the country, converting the fertile soil into sandy waste or gravelly barren land—the residue of the overrich soil, after having had all its fertilizing particles washed out of it by the action of surface drainage.

The loss thus incurred in the cultivated area is more serious than any damage caused by saline efflorescence in the Duab, as the latter is temporary and remediable in course of time, but the

former is almost irrecoverable and permanent after it has once reached a certain stage. Under the circumstances the matter deserves the most grave and serious consideration of Government with the object of introducing measures for the prevention of further loss, if not for the restoration of part of the land destroyed by the causes described.

With the results of surface drainage above described before us, it is not surprising that the fertility of the Bundelkhand soil has deteriorated, and that the spring levels have fallen to a depth at which irrigation is rendered almost impossible.

In regard to *lake irrigation*, it seems that none of the old lakes are provided with any extensive irrigation works, and it appears that irrigation from lakes was limited to the marginal land which was effected by the system of lifts or *dal*, and to the land lying below the lake, supplied with water by percolation. It is, therefore, clear that the lakes were not constructed for the primary purposes of direct irrigation, but that the constructors had in view the more important object, which now-a-days is designated "indirect benefit," that is, the raising and keeping up of spring levels, equalizing the temperature by supplying humidity to the atmosphere, and providing pasture for cattle, etc., and no doubt these are the principal objects for which lakes should be constructed.

Irrigation from wells was certainly the principal mode of irrigation practised in the ancient times, and it is my firm belief that it is even now the only practicable system, and by the general introduction of which the country would derive a permanent benefit. That this loss of the means of irrigation throughout the country is due to the fall of spring levels is unquestionable. The existence of stone-mills, wells and other irrigation works proves the use of irrigation at the places where they stand, but now in these places the spring level has gone down to 100 feet below the surface, and thus land has deteriorated into an unculturable waste. There must of course be many theories to account for this; and different ones must be suitable to different parts of the country. For this Bundelkhand province, I not only agree in considering the rapid drainage of rain water from the surface of the ground, as one of the causes which have affected the spring levels of the country, but from observations made in the course of twenty years' experience in these parts, I am quite convinced that it is the principal, if not the sole, cause of the phenomenon in question. The reverse conditions are also to be found wherever water is stored or by the nature of the soil allowed to be absorbed into the

ground; there the spring levels are found to lie close to the surface. The spring levels in the wells at Magarpur, Jawan Sakrar, and many other neighbouring villages, are kept up close to the surface by the percolating influence of the Arjar lake. Fruit and timber trees of all kinds thrive and grow to an immense size along its course, and ploughing is rendered easier there. The same may be said of all villages situated in the vicinity of other lakes. The construction of the Pachwara lake has had the effect of raising the spring level of wells all round it for several miles, as shown by the registers kept up by the Irrigation Department. All these facts, I trust, go to prove that I have not based my convictions on mere hypothesis.

There is one more method of improving the conditions of Central India which I should like to mention before closing this article, and that is the improvement of communications. A good deal has been done already in opening railways and main roads, but the feeder lines of communications are very difficult, which prevent people from getting their produce to market and moving about the country. There is no possibility of finding funds to make these minor roads anything better than fair weather lines, but communications would be greatly improved if the available money was steadily spent at the difficult points, *i.e.*, in easing the descents into *nallahs* and ascents over passes. Over the rest of the roads nothing is required except the removal of rocks or obstructions, and no money should be ever laid out in raising tracks unless there is every promise of metalling them in the near future.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

Bulletin No. 54 1915

Agricultural Research Institute, Pusa

Second Report on the Improvement of Indigo in Bihar

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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Second Report on the Improvement of Indigo in Bihar.

I. Introduction.

THE results obtained, up to the end of 1913, on the improvement of indigo in Bihar were published by the Bihar Planters' Association in January of last year and copies were then distributed to the members. It is not proposed to recapitulate here the contents of the first report but to deal with the progress which has been made during the year 1914.

There are five main directions in which the indigo industry can be developed by scientific methods. These are as follows:—

(*a*) The production of an ample supply of good, well-grown seed at the lowest possible cost and with the least trouble to the planter.

(*b*) The production of the maximum yield of indigo and of *seeth* from the plant now grown.

(*c*) The improvement of the plant by selection so that the yield of indigo and of *seeth* can be still further increased. The selection work, both on Java and on Sumatrana indigo, is in progress at Pusa and the results will be published next year.

(*d*) The preparation of finished indigo, in a standard form of high purity, suitable for the Home dyers.

(*e*) Indirect improvements, such as the production of more valuable cover-crops for Java indigo and the discovery of methods of increasing the efficiency of *seeth* as a manure.

The present paper deals with the progress made in establishing the seed supply, in improving the yield of indigo and also in finding a more valuable cover-crop for the Java plant. Nothing has been attempted in the direction of studying the manufacturing process

with the view of discovering the best way of producing pure indigotin direct from the plant. This is not necessary for the local trade but it will have to be taken up if natural indigo is to make any progress in the European market. One of the great advantages of the synthetic product is that it is easily manipulated in the vats, whereas natural indigo varies greatly in composition and dyeing power and therefore requires expert supervision. Under modern conditions of production, this is a great disadvantage.

II. The Manufacture of Indican.

From the standpoint of the planter, the indigo plant is grown mainly for the sake of the indican in the leaves. There is a bye-product called *seeth*, which consists of the plant residues after extraction and which is a very valuable manure. In the manufacturing process, the green plant is steeped in water, the indigo is precipitated, collected into cakes, dried and sold as a dye. It is usual to apply the term manufacture to the process of converting the indican in the cut plant into indigo cakes in the factory. This, however, is not the whole matter as the indican itself has to be manufactured first of all by the growing plant. The present section deals with the manufacture of indican by the plant and with the conditions under which this process goes on. It will be clear that this is the centre of the whole subject and that *the future of the indigo industry in Bihar will depend, first and foremost, on the capacity of the planting community to apply the principles set forth below and make the plant produce the maximum amount of indican.*

Indigo is a leguminous plant and, like all members of this order, is characterized by a high percentage of nitrogen in the seeds. This nitrogen occurs in the form of proteids and is placed there by the plant for the sole purpose of nourishing the seedling in the first stages of existence and supplying the protoplasm of its growing cells with nitrogenous food until it can lead an independent life.

When sown, the indigo seeds at first make no growth above ground beyond the two small seed-leaves. All the development is subterranean in the form of roots, and, at a very early stage, and before the first real leaves are produced, swellings, known as nodules, begin to appear on the roots. Soon afterwards, indican can be detected in the first real leaves but this substance has not yet

been found in the seed. These root-nodules are of the first importance in indigo (as in all leguminous crops) and, as will be seen later, everything in indigo cultivation and also in the separation of the indigo from the green plant in the factory, depends on the successful working of these root-nodules[1] and of the roots.

The essential points about these nodules are two. In the first place, they contain bacteria (*Rhizobium*) which have the power of assimilating the free nitrogen gas of the atmosphere and working this up into materials from which the indigo plant makes the proteids it requires and also the indican in its leaves. In a sense, the first stage in the production of indican is the nodule of the indigo root and the source of this indican is the nitrogen of the air. In the second place, the food of the bacteria in the nodules is supplied by the plant and, for this purpose, substances of the nature of sugar are passed down from the leaves into the nodule to feed the bacteria. The arrangement is a true partnership between the bacteria and the indigo plant. The bacteria produce from the air the materials for making proteids and indican, in return the plant feeds the bacteria with sugars formed in the leaves. Leguminous plants, however, if grown in soil rich in nitrates, do not form nodules but absorb the nitrates direct in the same manner as other plants do. These essential facts of the work of the nodule, in the plant economy, must be clearly grasped at the outset as on this depends the understanding of this paper and the perception of the principles on which the improvement of indigo depends. It must also be remembered that those parts of the indigo root which absorb water and minerals also require air and will not work in the absence of oxygen gas.

The development and activity of the root-nodules of indigo take place best when the plant is grown on somewhat poor land. On such land, the soil contains little nitrate, and, accordingly, the nodule-factories are working at high pressure to supply the proteids required. Large amounts of the nitrogen and oxygen of the air are used up and the leaves of the indigo become rich in indican. Every planter knows that indigo grown on rather poor land (*zilla* indigo) gives the best yield of finished indigo and often the best colour. Poverty of soil in nitrates is one of the conditions for the

[1] The well-being of all leguminous crops in India depends on the aeration of the root nodules. It is true that the place of leguminous crops in agriculture has long been understood and the rôle of the nodule is now recognized. The agriculturist, however, does not always appreciate the needs of the nodule itself.

production of numerous nodules on the roots and incidentally of high indican storage in the leaf.

When indigo is sown on rich land, containing a high proportion of organic matter such as *seeth,* the number of nodules formed on the root is small and the bacteria in them do not work at any great pressure. In such soil, nitrates are formed in abundance and the indigo plant then behaves like tobacco and takes up its nitrogen by way of the root-hairs, in the form of nitrates dissolved in the soil water. Under such circumstances, the growth is rapid but little indican is accumulated and, if such plant is steeped, it gives a small proportion of indigo and moreover of poor quality indigo. This fact is also well known to planters and the inferiority of the crop from highly manured land, compared with *zilla* indigo, is understood by all.

The activity of the root-nodules reaches its maximum about the time the plant is ready to flower. At this period, the leaves are also rich in indican. At this time, however, the indican in the leaves begins to be called upon by the plant and to be utilized by the flowers and developing seeds. It is said that if the indigo crop bursts into flower, the yield of finished indigo will fall off and the colour will suffer.

The activity of the nodules depends on two main factors—a full, continuous supply of air from the atmosphere and a supply of food from the leaves for the nodule bacteria. If either of these two things is interfered with, the nodule-factory does not work. As regards the supply of air to the soil round the nodule, this is at first an easy matter in Bihar provided the surface-soil is well and deeply cultivated and if crusts, formed by rain, are broken up whenever they occur. When the monsoon sets in however, difficulties in the air-supply of the nodules begin. If the monsoon is short and there are no large falls, the nodules get enough air and, if there is a succession of such years, the air-supply in the soil is abundant and Java indigo reaches its maximum development. If, however, there is a heavy rainfall so that the soil is packed by rain and the air spaces destroyed and filled with water for long periods at a time, then the supply of the essential air to the nodules and to the roots generally is cut off and the activity of the whole root-system, including the nodules, is stopped. At the same time, no further indican can be produced. When this happens, the whole economy of the plant is upset and it cannot manufacture any more food. A starvation period sets in and the reserves are called up. As at

flowering time, there is an immediate run on the reserve indican and this is consumed. If the plant in this starving condition is cut, it will give a low yield of indigo of poor colour just as flowering indigo does. As the starvation process proceeds, the plant begins to look unhealthy, the leaves fall and alter in colour and at last the stage, known as the wilt disease, appears. This is not a disease but the last phase in starvation, resulting from the destruction of the nodule-factories and of the absorbing portion of the roots, the activities of which have come to an end. This has been brought about by the cutting off of the air-supply by the heavy rains consolidating the soil and filling its pore-spaces with water. This cutting off of the air-supply is not due altogether to the rain which falls direct but is partly produced by the surplus water which runs off higher lands towards the low places. If this run-off from other areas could be prevented, the damage could be lessened and it is here that the Pusa method of drainage comes in to assist the indigo plant and the indigo industry. We should expect if the above is true, that indigo grown on land heavily manured with organic matter would show wilt sooner than indigo grown on poor land. The former has very little stored indican in its leaves and is not in a proper condition to withstand a famine. Experience shows that this is so, and that these heavily-manured plants are very prone to wilt and even die off completely before the plants on poor land have used up all their stores and begun to show signs of the trouble.

Besides cutting off the air-supply, the activity of the nodules can be interfered with if the bacteria in them are not fed by the plant. When young Java indigo, sown in August for seed, is cut down to the ground in October when about a foot high, practically all the plants die and very few shoot again. At this stage, little or no reserve food has been deposited in the roots and the nodules die of starvation. A few plants, however, just manage to survive and here again the new growth is wilted. At this stage, there is no reserve laid down and the whole plant rapidly dies of starvation.

The importance to the indigo crop of the nodules and of the absorbing roots is manifestly very great. Any interference with the partnership between the plant and the bacteria means a loss of indican and any serious trouble means the death of the plant, a condition which is reached through a wilting phase. The successful management of the indigo crop now becomes plain and simple and consists in running the nodule-factory to its highest pitch. Not only is the yield of indigo thus increased, but the condition of the finished product is improved and good colour results.

III. The Improvement of the Yield of Indigo.

It will be clear from the preceding section of this report that the improvement of the yield of indigo depends on the supply of air to the roots of the plant and to the maintenance of the aeration of the soil. It will be equally clear that the present practices in Bihar in growing Java indigo are about the worst that could be devised and that, in the past, the indigo plant has never had a proper chance. There has been no attempt at proper cultivation and nothing has been done to increase the air-supply by means of surface drainage. The crops obtained have been the result of chance; sometimes the colour has been good but most frequently it has been poor and only a low price has been realized.

The improved methods of cultivation that should be adopted with both Java and Sumatrana indigo are indicated in this section.

Cultivation of Java indigo. This plant is usually sown in October under a *rabi* cover-crop. As soon as the cover-crop is removed, the surface should be broken up as deeply as possible by means of lever-harrows.[1] In this way, the soil is aerated and a full supply of air finds its way to the roots. The indigo at once responds and new, healthy growth takes place. This harrowing must be done as soon as the cover-crop is taken off and before the land bakes and gets foul with weeds. It must be thoroughly done and two to three inches of fine soil must be left on the surface. Weeds are also removed by the harrowing and the moisture is conserved. The main object, however, is to supply the nodules with air so that they can make new growth and store up indican. Any crust which forms by rain must be broken up by the harrows, otherwise the air-supply is cut off.

When the plants are large enough towards the end of April or early in May, the indigo should be cross-cultivated, as deeply as possible, with the five tine spring-tooth cultivator.[2] A few plants may be uprooted but this does not matter as the indigo must start the monsoon with as much air in the soil as possible.

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[1] The best type of lever-harrow to use is the two-section harrow made by the Massey Harris Company, Toronto, Canada, price 12·90 dollars, f. o. b., New York. The orders for these harrows should be pooled by the Planters' Association and the makers should be instructed to crate the wooden bars, otherwise these will disappear at Calcutta during the unloading process at the docks. One pair of Bihar cattle will draw these harrows easily.

[2] An agency for the supply of these cultivators has been established in Muzaffarpur. If the local supply is inadequate, orders should be sent to Messrs. Volkart Brothers, Lyallpur, Punjab.

The land on which indigo is grown should be drained by the Pusa system so that each field has to deal with its own rainfall only. This method was referred to in the last indigo report and it has been carried out, with great success, on the Dholi estate. Any planter can now see for himself this method in use on the large scale. This drainage system controls the rainfall and prevents waterlogging to a great extent. Consequently, under this method, the air-supply in the oil lasts longer and the danger of wilt is diminished. Further, by keeping the nodules working by the increased air-supply, the colour of the finished indigo will be improved.

The adoption of these methods in most cases will result in two good cuts of indigo. After this, the stumps should be dug up and the land put into *rabi* crops. If this is not done, the land gets foul with weeds. None of this indigo should, under any circumstances, be kept for seed.

Cultivation of Sumatrana indigo. This plant is sown at the beginning of the hot weather, and, in order to bring the moisture near enough to the surface for germination, the land has to be compacted to a great extent. By this means the aeration of the soil is partly destroyed and the young roots are liable to suffer from want of air. As soon as the plants are large enough, they must be cultivated with lever-harrows and this must go on till about three inches of loose soil have been worked up. The root system of this plant is not as strong as that of Java indigo, so the spring-tine cultivator should be used with care. After the first cut, the land should be worked up and aerated by means of the spring-tine cultivator or the ordinary plough.

When sown on moist, low-lying lands, the soil should be well cultivated beforehand so that there is a good supply of air. Any loss of moisture will make little or no difference as it is air—not water—which is important in such cases.

Pruning indigo at the first cut. It will be clear, from the point of view of the plant, that the whole economy will be upset when it is cut down completely at the first cutting. The transpiration current will be stopped and the stumps will bleed. The nourishment of the bacteria in the root-nodules will be interfered with and a great deal of the reserve food of the plant will be taken away. A few leaves should be left to carry on the transpiration current and also the naked branches at the base of the plant. This is a great advantage in wet years like 1913, when at Pusa the total yield of leaf was increased by about 30 per cent. by this means. This method of taking the first cut involves no extra expense and only

a little trouble in teaching the coolies. It is no advantage to take the old wood to the steeping vats, indeed it is a positive disadvantage, as the cost of transport is increased and the concentration of the liquor is lowered. The *seeth* is also of less value. To the indigo plant, struggling to make new growth in semi-waterlogged conditions, the maintenance of the transpiration current by the few leaves left and the reserve food in the old wood make all the difference between life and death and besides accelerate the new growth.

The methods of cultivation advocated in this section were partially put in force on the Dholi estate for the 1914 crop. The result was a record yield of 23·5 seers of indigo and of 170 maunds of green plant per bigha. This is only a beginning and still better results are easily possible.

IV. The Seed-Supply of Java Indigo.

An ample supply of well-grown seed of Java indigo is the first condition of progress in rehabilitating the Bihar industry. As pointed out in the first report, the area under this crop fell from 70,000 bighas in 1910 to 15,000 bighas in 1913 largely on account of the difficulty in growing the seed.

In connection with the seed-supply, it must be remembered that Java indigo is a leguminous crop and, in common with other members of this group, the seed contains a high percentage of proteids. Leguminous plants assimilate atmospheric nitrogen in their root-nodules and by this means manufacture substances which can be worked up into new proteids in the leaf. Until the nodules are formed on the young roots, they are dependent on the reserve proteid stored in the seed. On this account, it is essential that when leguminous seeds are sown they should be well ripened and of good quality. Hence, too much attention cannot be paid to the seed-supply in indigo. With poorly-matured seed, the seedlings have no proper chance of establishing themselves and an uneven crop, full of weeds, is bound to result. During the last few years, the quality of the seed sown has been very poor and this is one of the reasons why the crop has degenerated so markedly.

In the first report, the following recommendation was made on the subject of growing seed:—

"The Pusa experiments on the growth of Java indigo for seed point to very definite conclusions. In wet years, like the present, a crop of really good seed is, as a rule, impossible after cutting the indigo for leaf. In future, leaf-growing and seed-growing

PLATE I.

JAVA INDIGO FOR SEED ON THE DHOLI ESTATE.

should be regarded as separate things. For seed, Java indigo should be sown about the middle of August on high-lying, well-drained lands. The seed should be sown in lines, about two feet apart, so as to promote branching and ensure abundant pollination. At first, cultivation and crust-breaking should be carried out with the lever-harrow but when the plants increase in size, interculture and weeding should be done by means of the Planet Junior hand-hoe. Grown in this way, indigo escapes the so-called disease and large crops of good, well-grown seed can be obtained."

This method gave good results on the Dholi estate and a fine crop of seed was obtained in February 1914. The plants, however, were rather too thick, but during the present crop they have been thinned considerably and stand about nine inches apart. The result is shown in Plate I, and it will be seen that an exceptionally fine crop has been obtained. The weight of seed will be determined and the figures published in the next report. As far as can be judged at the time of writing (December 16th), the yield of seed will not fall far short of ten maunds to the acre. Similar results have been obtained at Pusa this year and, as far as this method of seed-growing is concerned, the experiments carried out at Pusa and at Dholi in 1913 and 1914 have been uniformly successful. There is no doubt that this method of growing seed is very satisfactory and that it should be adopted on all indigo estates.

The production of seed now offers no difficulty and yields of 8 to 10 maunds per acre can be obtained. High-lying lands, in a clean condition, must be selected for the crop, and it will be a distinct advantage if the field is drained on the Pusa system. Sowing must be done during the first half of August and the ordinary indigo drill, in which alternate shares have been removed, can be used. As soon as the plants are well established, the surface crusts should be kept broken with the lever-harrows. This is essential if the best results are to be obtained as indigo requires air for the root-nodules and these nitrogen factories will not work properly if there is a crust (*papri*). About the middle of October after the *hathia*, the plants should be thinned by hand and they should stand about nine inches apart. The crop should now be cultivated as deeply as possible both ways with the five tine spring-tooth cultivator, so that the upper four inches of soil are worked up into a fine mulch. On no account should this cultivation be omitted. Weeds are killed and the roots are given a full supply of air. The root-hairs cannot work without oxygen while both oxygen and nitrogen are essential raw material for the nodules. It has been stated above

that indigo seeds are very rich in nitrogenous reserve materials (proteids). This material is made by the plant from atmospheric nitrogen and the first stage in the process takes place in the nodules of the root. Air must therefore reach the nodule in abundance, and, for this reason, the deep cultivation for seed in early October is essential. If this is not done and the indigo plants are left in the hard, unbroken soil,, it is observed that they set very few seeds and also begin to look unhealthy. The nodule-factory cannot work for want of raw material and, in consequence, the supply of materials for the seeds is not available. The seeds are therefore not formed. A full supply of air to the roots is necessary for the production of a good crop of indigo seed.

As pointed out in the first report, the proper spacing of the seed plants is an important matter. The flower of Java indigo is a bee flower and the visits of these insects are necessary to bring about pollination. If the plants are too close together, they generally flower at the tips of the branches only and, even if flowers are formed in the dense shade, the bees do not visit them. Air and light are necessary for the production of side-branches, for the formation of flowers and for ensuring the visits of bees.

V. Indirect Methods of Improving the Indigo Industry.

There are two indirect methods of improving the indigo industry, namely, the provision of a more valuable cover-crop for Java indigo and the better utilization of *seeth*.

Cover-crops. As regards a better cover-crop for Java indigo, a new variety of wheat, Pusa 4, has been introduced which can be grown with indigo on high lands. This wheat is a rapid grower, does not tiller much, has a very strong straw and is provided with few leaves. On this account, the young indigo plants get a full supply of light and air and the two crops do very well together. To give the indigo roots enough air, the mixed crop should be well cultivated in November with the lever-harrow, the tines of which should slope backwards so that none of the wheat is pulled out.

This wheat has been grown with indigo on the Dholi and Hathowri estates for some years and has done uniformly well. A general average of twenty maunds of grain to the acre can easily be obtained. The wheat stands up well and is easily cut by a reaper, while in threshing there is no trouble. The grain separates out easily in the machine and the sample is a very fine one. It is much liked by the people and round Bunhar and Hathowri the ryots

are taking it up. A large supply of this wheat is available for seed on the Dholi estate this year. This variety is likely to fetch a premium at the Calcutta mills, so an effort should be made by the Indigo Planters' Association to establish a grade of Pusa 4 in Bihar for the Calcutta market. Later, when the cultivation spreads, shipments to England can be made.

The efficiency of seeth. As is well known, *seeth* is a very good manure for tobacco, but its value depends to a great extent on its power of aerating the soil and of giving the tobacco roots an ample supply of air. Experiments are in progress at Pusa with the object of getting a better return from *seeth*. Evidence has been obtained that if the tobacco lands are mixed with small pieces of tile (*thikara*), the amount of organic matter for the crop can be reduced. The cost is not very great and a plot which was improved at Pusa in this way nine years ago still shows its superiority. If the present supply of *seeth* can be made to produce the same results on two or three times the area, the factories will be materially assisted and the indigo industry will receive an indirect benefit. The large scale experiments on this subject will be completed by the end of the present year and, if the final result is successful, the method will be brought to the notice of the planters.

On February 10th, 1915, a large number of the leading members of the Bihar Indigo Planters' Association visited Dholi in order to see the improvements, referred to in the above report, in indigo cultivation and in drainage, carried out on an estate scale.

The Pusa system of surface-drainage was explained in detail and areas of the estate were shown which have been transformed by surface-drainage in a single year. In one case, a large area which previously gave little or no return, was seen in chillies, the rental of which is now ninety rupees per bigha. In another case, some of the land, which had previously been rendered very infertile by scour, was seen under tobacco under a rental of one hundred and forty rupees a bigha.

There was a large area under Java indigo bearing a fine crop of seed and also mixed crops of Pusa 4 wheat and indigo. Lever-harrows and spring-tine cultivators were shown at work. This visit was a great success and the demonstrations were followed and discussed with the closest interest. It is hoped that meetings such as this will take place every cold weather and that it will be found possible to combine visits to Dholi and to Pusa.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 55 1915

Agricultural Research Institute, Pusa

The Manufacture of Jaggery in South India

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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The Manufacture of Jaggery in South India.

DURING the last three years, first in the Madras Presidency and subsequently in the Mysore State, I have been conducting experiments with power-driven sugarcane mills to ascertain the conditions under which they can be usefully employed. A number of such plants had been installed in various parts of India but apparently with little success and it seemed to me urgently necessary to discover why such an obvious improvement in the methods of dealing with the sugarcane crop had not proved acceptable to the sugarcane growers.

It is admitted by every one that the ordinary country methods of crushing cane are primitive and inefficient. Numerous tests made in the South of India show that the average country mill can deal with about 400 lbs. of cane per hour and that it is a good day's work for a pair of bullocks to crush a ton of cane. An average sugarcane crop in the Madras Presidency will yield about 20 tons of cane, and allowing for off-days, it will take a *raiyat* with a single pair of bullocks about a month to crush it. The work is very hard on the cattle and causes them to deteriorate very rapidly.

For no agricultural operation is the employment of power so easy and at the same time so necessary ; yet, the use of power-driven sugarcane mills so far has made no head-way. A power mill may be of almost any capacity, but for practical purposes the smallest size will crush about 800 lbs. of cane per hour and has an output equal to that of two country mills. Driven by a small oil-engine the mill, however, can be run day and night, or say four times as long as a pair of bullocks can work, so that its capacity is equal to that of two country mills each worked on shifts of about 4 or 5 hours each with four pairs of bullocks. Such a mill will deal with about 8 tons of cane in 24 hours or an acre of cane in 2½ days. In most parts of the country it is possible to arrange for a cutting season of 100 days, so that a small mill of this kind will crush 800 tons of cane in a year ; equal to the produce of about 40 acres of cane cultivation. The mills used at the experimental installations were, however, of larger capacity than this. Each mill was provided with three rollers of 12 inches diameter and 18 inches long and was driven by a 12 H. P. oil-engine. The capacity of such a mill may be taken at one ton of cane per hour, but with good cane and careful feeding this may easily be exceeded by 50 per cent. Such a mill can deal with about an acre of cane a day or with 100 acres in a season.

The first mill was set up at Singanallur in the Coimbatore District and was worked in the latter months of 1912. In 1913 three similar plants were established in the Mysore State and started work in the month of April. In 1914 a second plant was set up at Hospet in the Madras Presidency and early this year a sixth installation has started work at Shikarpur in the north of the Mysore State. In each case the plant has been set up in a neighbourhood where sugarcane is largely grown; and the *raiyats* were invited to bring their cane to the mill to have the juice extracted and manufactured into jaggery. It was not expected that there would be, and from the very out-set there has been, no trouble with the mills and the *raiyats* generally credit them with extracting about 10 per cent. more juice than they themselves can obtain with iron mills worked by bullock power. At the end of the first season's work at each installation the results obtained were very similar. It was found that the *raiyats* were willing to cart their cane a very considerable distance to avoid the trouble of dealing with it themselves; but the rates they were willing to pay for the manufacture of jaggery involved working the installations at a loss. This loss was obviously due to the total unsuitability of the indigenous methods of boiling down the juice to jaggery. The $12'' \times 8''$ roller mill crushing a ton of cane per hour supplies in that time sufficient juice for two country pans, and it takes from 5 to 6 hours to work off a pan of juice. To keep the mill going, at least 12 pans are required. Each pan is put over a separate furnace and requires a separate fire-man and when these men were compelled to work off two pans a day, there was generally trouble and not a few pans were burnt or otherwise spoiled. It was impossible to secure any regularity in the firing with the result that sometimes 3 or 4 pans would be ready at the same time and there was not a sufficient number of men to attend to them. It was only possible for the Superintendent of the factory to get through the day's work with an inordinate amount of worry and trouble and by employing a large and expensive staff of men. Night work was found to be impracticable. Every day there was a large loss of heat due to the cooling down of the furnaces after one or two pans of juice in each had been worked off. With hired coolies as fire-men, it was found difficult to get them to use the megass and large quantities of fire-wood had to be supplied. By itself, the megass was insufficient to boil down the juice but the hired men practically refused to use it and at the end of the season there was a large stock of megass at each mill that had not been burnt.

In 1913, at the three installations belonging to the Mysore Government, 14,822 maunds (1 md. = 25 lbs.) of jaggery were made and the expenditure on fire-wood alone was Rs. 3,228. A review of the season's work showed that it was imperatively necessary to devise improved methods of boiling down

the juice and that unless this was done, it was certain that these small installations could not be made successful.

Action along two lines was possible. The calorific value of the megass was known to be more than sufficient to provide all the heat necessary and it was decided to provide a suitable megass-burning furnace arranged either

(1) to evaporate the juice in open pans placed over suitably constructed flues; or

(2) to generate high pressure steam in a boiler and use this steam to evaporate the juice.

The first method of dealing with the problem was taken in hand at once and a number of trial furnaces were constructed, finally resulting in the system, which it is the object of this paper to describe. The steam heating arrangements involved a somewhat lengthy correspondence with makers of such machinery in Europe and the order for the plant was not placed till after the outbreak of war and up to the present time the plant has not been received. This might have been very inconvenient, but fortunately the first method of dealing with the problem has proved so successful that the results of the second method, whatever they may be, are already to some extent at a discount. The new furnaces were in use at the three Mysore installations throughout the whole of last year and though in other respects the conditions under which the milling was done were very unfavourable, 13,683 maunds of jaggery were made without any expenditure on fuel and at all the three installations a small profit was realized without increasing the manufacturing charges of the previous year. Worked to their maximum capacity, as these installations should be, during the cane season, the output of jaggery from each should be about 6,000 maunds in a month, and the three installations should have turned out 60,000 maunds in the year. As a matter of fact, entirely through the failure of the crops, the output was less than one-fourth this amount and instead of being obtained in the months between January and June was scattered over every month in the year. In the table in the Appendix, figures are given for the number of hours the mill was worked and the number of maunds of jaggery manufactured at each of the Mysore installations.

It is only proposed to describe the final form of the furnace in which the megass is burnt. A single unit consists of three evaporating pans arranged in series as a cascade. The dimensions of the pans may vary within fairly wide limits. A convenient size has been found to be, for rectangular pans, 6 feet by 4 feet on the bottom and 7 feet by 5 feet at the top. The depth of the pan is 18 inches. The depth of the bottom pan may be

conveniently increased to 1 foot 9 inches as in this pan the final operations take place and there is a great deal of frothing of the juice. This pan is provided with a hinge along the front bottom edge so that it can be conveniently tilted by the arrangement shown in the drawing. The two upper pans must each be provided with a pipe and cock so that the juice can be run from an upper pan into the next lower one. These pans are placed over flues arranged as shown in the drawing. The most important feature of the furnace is the sloping grate on which the megass is burnt. The combustion chamber is placed just below the finishing pan and is inclined at an angle of about 45 degrees, sloping backwards and upwards, and terminating just below the front edge of the finishing pans. The grate may be either a cellular structure of fire brick or of cast iron bars. The megass is fed into the furnace through a transverse slot placed just below and parallel to the front edge of the finishing pans. It is advisable to construct a platform of considerable size in front of the finishing pans so that there may be plenty of room on which to store the megass or to conduct the operation of emptying the jaggery out of the finishing pan into the wooden bucket in which it is conveyed to the moulds in which it is cast. Brick and mud can be used for the construction of the furnace and as shown in the drawing, archways may be employed to lighten the structure and afford space in which the jaggery may be stored, the furnace should be lined with fire bricks and preferably also the flues. The chimney should be of iron sheeting and the roof is best made of galvanized iron supported by light trusses and carried by rolled steel beams used as columns.

It is not necessary to go into too great a detail as to the arrangements of a jaggery factory fitted with these furnaces. The engine and mill should be housed in a galvanized iron shed and in front of the mill there should be a large open shed in which the sugarcane can be stacked till it is passed through the mill. The megass can be removed from the mill by hand and spread out in the sun to dry. Roughly, it will contain about 50 per cent. of moisture and about half of this can be removed by drying in the sun. The juice from the mill is run into a rectangular tank which may be best made of aluminium and fitted with screens of that metal to remove the powdered megass, which is carried away in the juice. From these tanks a small juice pump raises the juice into one or the other of the two storage tanks, which may also be constructed of aluminium. Ordinarily, the juice passes through these tanks into the upper evaporating pan. But when dealing with the canes of different *raiyats,* it is convenient on starting with a new lot of cane to run the juice into the aluminium tanks till all the juice obtained from the previous *raiyat's* cane has been run out of the top evaporating

pan. At least once in every 24 hours the whole system of pipes, tanks and pans should be cleaned out with fresh water and this is easily done by running some hot water from the cooling tanks of the oil-engine into the juice pump and thence pumping it into the aluminium tanks from which it is run down through the series of evaporating pans. To keep a 12″ × 18″ roller mill at work, 3 sets of these furnaces are necessary and it is convenient to have a fourth as a stand-by in case, during the working season, any repairs should be necessary.

Not only has the full question been solved but in the working of these furnaces all the labour troubles have also been eliminated. Firing presents no difficulties as the megass is simply dropped by hand into the feed slot. After the first start, the cycle of operations takes about one hour and 20 minutes and two jaggery boilers can easily deal with three pans. It is easy to supervise operations and once the staff are trained, it is only when the *raiyats* fail to supply cane for milling that any interruption occurs in the smooth working of the plant.

In the Appendix detailed estimates are given of the cost of setting up sugarcane crushing plants of this type. One estimate is for a small roller mill with one set of furnaces and does not include the cost of buildings as these may often be available. The other is for a larger mill capable of supplying juice for four sets of furnaces and includes the cost of suitable buildings and sheds at average rates for the South of India.

During the cane crushing season, it is not necessary to stop working for more than 2 hours a day. Two shifts of men must be employed and the working expenses for an output of 200 maunds of jaggery a day may be estimated as follows, based on an establishment paying the following monthly wages :—

	Rs.
1 Superintendent at Rs. 30	30
2 Drivers at Rs. 20 each	40
4 Jaggery boilers at Rs. 20 each	80
4 Cane feeders at Rs. 15 each	60
10 Women coolies or boys at Rs. 6 each	60
4 Firemen at Rs. 12 each	48
Running expenses of engine at Rs. 5-8 per day	162
TOTAL	480

With an output of 6,000 maunds in a month the charge per maund (25 lbs.) will be one anna and 2 pies. Assuming the capital cost of the installation as Rs. 10,000 and allowing thereon 12½ per cent. for interest and depreciation per annum and further assuming that the whole of this amount is to be paid during a season of four months, the standing charges per month will amount to Rs. 312-8-0 equal to 10 pies per maund, making the total cost of the manufacture of jaggery, two annas per maund of 25 lbs.

The smaller installations are usually run by the owner and his servants. If milling for other *raiyats* is done they usually assist in the work. The out of pocket expenses for milling are therefore no greater but actually less than with the larger mills. Many *raiyats* in the South of India look after their own oil-engines and professional drivers are not employed. These small mills are usually installed at a pumping station and the same engine drives both pump and mill.

At the present time the installations at work, both in the Mysore State and the Madras Presidency, charge from 4½ annas to 5 annas per maund of jaggery made and as in addition, the *raiyats* have to bear the cost of carting the cane from the fields, it may be taken as fairly certain that the advantages of a mill are already realized and that there is a sufficient margin to induce the flow of capital into this method of manufacturing jaggery.

It has already been stated that the power-driven mill is credited by the *raiyats* with an extraction at least 10 per cent. greater than that which they can obtain with their own mills worked by cattle. At Kunigal recently, at the request of the *raiyats* in the neighbourhood, a comparative test was made between the old and the new methods of working. In each case 750 pounds of cane were weighed out and whilst the *raiyats* obtained from their cane 83 lbs. of jaggery, the Superintendent of the Kunigal Mill obtained 97 lbs., the excess of 14 lbs. being equivalent to an increased outturn of 16·8 per cent. The advantages of this new method of working may be stated in the following way : In the indigenous system, from a certain quantity of cane a *raiyat* will obtain one maund of jaggery worth, say Rs. 1-8-0 and the cost of manufacture may be assumed to be 4½ annas leaving him Rs. 1-3-6. If he takes the same quantity of cane to the mill, he will get $1\frac{1}{6}$ maunds of jaggery worth Rs. 1-12-0 and as the cost of manufacture will be only 2 annas, the net amount realized will be Rs. 1-10-0 as against Rs. 1-3-6, or a net gain of 33 per cent. This may mean double or even treble the net profits on sugarcane cultivation, which will be a great inducement to the extension of sugarcane growing. The principal merit, however, of this system of manufacturing jaggery is that it enables power-driven sugarcane crushing mills to be introduced and in future, a *raiyat* may safely undertake to cultivate as much cane as he has facilities for, without being faced with insuperable difficulties as to milling the cane when the crop is ripe.

There is not the least doubt that in the South of India, at any rate, sugarcane cultivation has hitherto been restricted by the number of cattle available during the crushing season. Doing away with the necessity for employing cattle to crush the cane removes this restriction and opens but a wide field for the expansion of the industry on much more profitable terms than has hitherto been possible.

APPENDIX.

Table showing number of hours worked and outturn of Jaggery by the Mysore Mills in 1913-14.

1913.	Chiksagere.		Kunigal.		Haravu.		Total.	
	Hrs.	Mds.	Hrs.	Mds.	Hrs.	Mds.	Hrs.	Mds.
April	197	1,757	58	407	46	151	301	2,315
May	232	2,249	88	691	56	277	376	3,217
June	186	1,659	203	1,545	155	867	544	4,071
July	13	180	132	904	169	1,140	314	2,224
August	...	...	108	654	257	1,700	365	2,354
September	...	...	21	134	82	567	103	701
TOTAL	628	5,845	610	4,335	765	4,702	2,003	14,882
1914.								
January	...	...	...	...	6	52	6	52
February	...	...	...	...	64½	426	64½	426
March	...	...	22½	159	142½	1,026	165	1,185
April	21	105	157½	1,189	11	71	189½	1,365
May	203	1,612	160	1,028	28	164	391	2,804
June	91	875	107½	627	...	...	198½	1,502
July	5	42	139½	928	15	80	159½	1,050
August	...	...	249	1,621	64	414	313	2,035
September	...	...	214	1,342	80	503	294	1,845
October	...	...	108	742	...	...	108	742
November	...	...	98	659	...	...	98	659
December	...	...	3	18	...	...	3	18
TOTAL	320	2,634	1,259	8,313	411	2,736	1,990	13,683

	Chiksagere.	Kunigal.	Haravu.	Total.
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Milling charges realized in 1913	1,615—7—3	1,185—12—10	1,430—3—9	4,231—7—10
Milling charges realized in 1914	561—3—10	2,356—12—0	707—14—9	3,625—14—7
TOTAL	2,176—11—1	3,542—8—10	2,138—2—6	7,857—6—5

1915.	Shikarpur.		Kunigal.		
January	7	62	..	...	Owing to the unfavourable character of the last cane-growing season there will be no milling at Haravu or Chiksagere.
February	144	1,253	36	237	
March	147	1,606	35	242	
April	...	...	261	2,078	
May			In progress.		

Estimated cost of Cane Crushing Plant with an output of 5,000 lbs. of Jaggery per day.

	Rs.
Machinery	4,370
Set of four Furnaces	3,200
Superintendent's Office	1,250
Engine Shed	650
Jaggery Store	530
TOTAL	10,000

Details of estimated cost of Machinery.

	Rs.
12 B. H. P., Oil-Engine	1,886
12″ × 18″ Sugarcane Mill	1,282
Driving Pulley for engine 14″ dia. × 12″	30
3 Water tanks for cooling and circulating water pipes	328
Gun-metal Juice Pump for Mill	252
100′ of 1½″ piping from Mill to Tanks	48
45′ of Belting 4″ × 4 ply	30
2 Aluminium Juice Tanks	114
Cement foundations and erection charges	400
TOTAL	4,370

N.B.—Railway freight not included.

Details of estimated cost of Furnaces and Evaporating Pans.

——	Per	Rate			Quantity	Cost
		Rs.	A.	P.		Rs.
Raw brick in clay	C. Ft.	0	0	6	7,579	237
Burnt brick in clay	„	0	2	0	1,821	228
Iron Girders	R. Ft.	0	11	0	586	403
Angle iron Truss 20′ centre	Each	20	0	0	9	180
Galvanized iron sheet roofing	Sqrs.	20	0	0	51·96	1,040
Fire brick lining for flues		Lump Sum				100
4 Sets of Pans		Do.				600
2 Chimneys		Do.				100
4 Dampers		Do.				20
4 C. I. Inclined fire grating		Do.				90
4 Pulleys with Brackets . . .		Do.				50
	Total					3,048
	Contingencies at 5 per cent. .					152
	GRAND TOTAL .					3,200

Estimated cost of Cane Crushing Plant with an output of 2,000 lbs. of Jaggery per day: Building excluded.

	Rs.
5 B. H. P. Oil-Engine	968
8″ × 8″ Sugarcane Mill	427
Driving Pulley for Engine, 14″ dia. × 12″	30
Water Tank for cooling and circulating water pipes	119
45′ of belting $3\frac{1}{2}$″ × 4 ply	29
Furnace complete, 1 series, without roofing	500
Cement foundations and erection charges	200
	2,273

N.B.—Railway freight not included.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 56

1915

Agricultural Research Institute, Pusa

Green-Manuring in India

BY

A. C. DOBBS,
Offg. Imperial Agriculturist, Pusa.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
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PREFACE.

THE compilation of this Bulletin was undertaken in response to a suggestion that the importance of green-manuring in India demanded a comprehensive survey of the work hitherto done in that connection.

The Bulletin does not pretend to be original, and in fact less excuse is perhaps necessary for the wholesale quotations taken from original papers, than for the representation in the compiler's own words, for the sake of brevity, of some of the facts collected by, and conclusions drawn by, the authors cited.

The compiler's thanks are due to the Directors of Agriculture who supplied him with all the materials at their disposal, to the authors of the original papers from which extensive quotations have been made and from which illustrations have been taken, to Messrs. Allan, Finlow, Harrison and Meggitt who have enlightened him on the subject from hitherto unpublished experience, and to Mr. S. D. Muley of the Office of the Agricultural Adviser to the Government of India who looked up a very large number of references on the subject — a few only of which it has been possible to quote specifically.

PUSA,

27th April, 1915.

A. C. DOBBS.

Green-Manuring in India.

PART I.

THEORY AND ESTABLISHED PRACTICES.

1. Theory of Green-manuring.

General.

The theory of green-manuring is based on a study of the factors that have been found to underlie fertility of the soil all over the world. The operation of these factors, on the positive side, is, in the main, exceedingly simple.

The soil, on which vegetation depends for its support and for the supply of a necessary minimum of mineral salts, has a certain physical and chemical constitution, determined primarily by its geological origin and the atmospheric influences to which it is exposed. Vegetation, in turn, affects the soil in several ways. Besides assisting directly in the mechanical disintegration of the soil and subsoil by means of its roots, and preventing excessive denudation by protecting the surface from climatic influences, it introduces a new factor, in organic or carbonaceous matter elaborated from the carbon dioxide of the air which is absorbed and built up to a high potential by means of the green surfaces which plants spread to catch the sunlight. This organic matter not only adds to the content and alters the physical constitution of the soil, but, with the whole array of reagents into which it is decomposed it may hasten very considerably the chemical decomposition of the soil, which, as also the underlying rock or drift, is more rapidly broken up by solutions of these organic reagents than by ordinary rain water. The greater part of the resulting salts are washed away, but such as are required by plants are absorbed and incorporated by them, and their organic remains thus provide not only a means by which a larger quantity of such salts are annually rendered available, but a reservoir in which a larger proportion of the substances essential to fertility are retained in circulation, within reach of vegetation, than is the case on barren soils in which there is no organic matter.

The physical alteration of the soil is also usually for the better, both the water-holding capacity and the permeability being, as a rule, brought nearer the optimum for plant growth by moderate additions of organic matter.

Besides these factors of mineral and vegetable matter, the bacteria and fungi form a most important factor in soil fertility. Not only is the decay of dead vegetation chiefly effected by these lowly forms of life, but some, of the bacteria at any rate, provide means by which the nitrogen of the air is 'combined' or 'fixed' and rendered available for the higher plants to which it is indispensible but which have no means of utilizing it directly.

Of the bacteria which have the power of utilizing free nitrogen, some live on dead organic matter, and when there is a sufficient supply of this, would appear to be capable of providing a very considerable quantity of combined nitrogen, per acre per annum.[1] But the better known and possibly more important 'nitrogen-fixing' bacteria are those which live in the nodules on the roots of most leguminous,[2] and of a few other plants, and it is on these that the greater part of continually cultivated soils would appear chiefly to depend for the supply of the combined nitrogen which, when water is sufficient, is commonly the weakest link in the chain of fertility.[3]

[1] In the Geescroft field at Rothamsted, an accumulation of 44 lb. of combined nitrogen per annum, under unfavourable conditions, is considered by Hall to have been due to such bacteria.—*Rothamsted Experiments*, John Murray 1905, pp. 139 and 140.

[2] *The Agricultural Ledger* No. 7 of 1894 contains notes on this subject by Professor Middleton, Dr. Leather and Sir George Watt.

[3] A good example of the amount of nitrogen that may be obtained from the atmosphere during the growth of a leguminous crop, is given by Hall (*Rothamsted Experiments*, pp. 9, 10 and 137). Part of the Geescroft field was sown with barley and clover in 1883, the clover being allowed to stand in 1884 and 1885. "At starting, the soil was analysed; the surface 9 inches contained on an average 2,657 lb. per acre of nitrogen ...... As a result of the three years' cropping ...., an average amount (per acre) of 319·5 lb. of nitrogen was removed, yet the soil contained, on analysis at the end of the experiment, 2,832 lb. of nitrogen per acre in the top 9 inches, or a gain of 175 lb. per acre in the three years; making a total, with the crop removed, of nearly 500 lb. of nitrogen per acre to be accounted for." The following table gives further details of this experiment:—

	1883 Barley and Clover	1884 Clover	1885 Clover
	lb.	lb.	lb.
Crop per acre (Dry matter)	3,457	7,649	3,325
Nitrogen in crop per acre	53·8	194·2	71·4
Nitrogen per cent. in surface soil	0·1081	...	0·1152
Nitrogen per acre in surface soil	2,657	...	2,832

PLATE I.

Fig. 1.

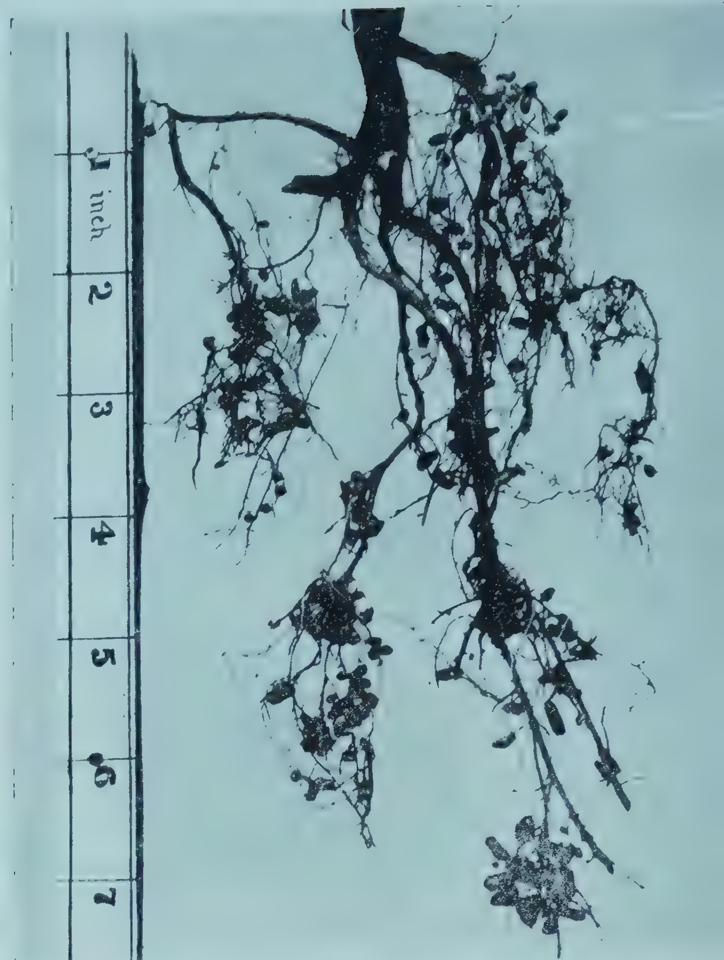

Fig. 2.

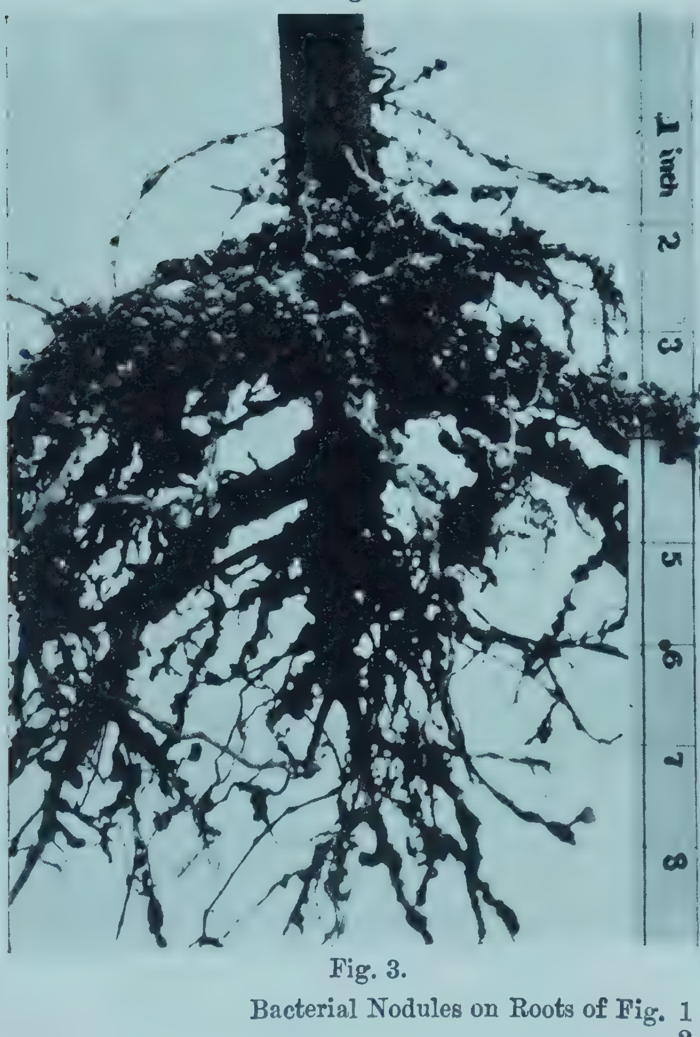

Fig. 3.

Fig. 4.

Bacterial Nodules on Roots of Fig. 1 Siris. (*Albizzia* sp.)
„ 2 Boga Medeloa. (*Tephrosia candida.*)
„ 3 Dhaincha. (*Sesbania aculeata.*)
„ 4 Nepauli Bhot mas. (*Glycine hispida* var.)

The plate opposite, taken from a paper by Mr. Claud Bald in the *Agricultural Journal of India*, Vol. IX, pt. II, shows nodules on the roots of various leguminous plants.

The importance of organic matter in cultivated soils—as improving their physical constitution and water-holding capacity, as a reservoir for the retention, in circulation, of plant food which would otherwise be washed away, and as a food for certain nitrogen-fixing bacteria—is thus apparent; and the peculiar value of certain leguminous plants, as a means of providing both nitrogen and organic matter in soils in which they are deficient, can be appreciated.

Such, broadly, are the considerations which have been adduced in recent years to explain the advantages of green-manuring—a practice which consists in the incorporation, in the soil, of vegetation of all kinds, and in the cultivation for this purpose of quickly growing crops, chiefly of the leguminous order, when opportunity occurs.

Application to India.

But these considerations apply with peculiar force to sub-tropical countries generally, and to India in particular. With its extremes of heat and cold, and its variable and unevenly distributed rainfall, India is essentially a country of forest and arable land. Once the virgin forest has been cleared, it becomes necessary to cultivate the land continually to obtain any considerable return. In contrast with the agricultural economy of countries where the rainfall is evenly distributed and the extremes of temperature are less, so that grasses and clovers will yield profitable crops for two or more years in succession without cultivation, it is, generally speaking, impossible to grow, in India, a field crop that occupies the ground for more than half the year and that does not admit of cultivation of the land in the hot dry season. But the result of constant cultivation is well known to be a progressive diminution in fertility, —from the 'virgin' condition in which a relatively large amount of circulating capital is available in the soil, to the 'worn out' stage when this capital has reached a minimum with the disappearance of organic matter. Moreover, in India, owing to the dearth of fuel in cultivated areas, the small amount of organic matter that might be returned to the land in the form of manure, is commonly burnt.

And in fact, Indian soils are found to contain very little organic matter compared with that found, for instance, in English agricultural land. On this point Dr. Voelcker in paragraph 58 of his *Report on the Improvement of Indian Agriculture* says: "On looking into analyses of Indian soils which have been recorded, and others which I have made

myself, I find that, with the possible exception of black cotton-soil, Indian soils are generally very deficient both in organic matter and in nitrogen. The following analyses will illustrate this :—

Organic matter and Nitrogen in Indian soils.

	Cawnpore Farm Soil (S. A. Hill.)	Soil from Arrah, Bihar (E. Kinch.)	Soil from Siripur, Bihar (E. Kinch.)	Dumraon Farm Soil, Bihar (E. Kinch.)	Three soils from Wheat-growing land in Sirsa District, Punjab (J. A. Voelcker.)		
Soil (dried at 212°F) contained—	Per cent.	Per cent.	Per cent.	Per cent.			
Organic matter and combined water .	2·20	1·74	2·77	5·53	0·63	2·67	0·65
Nitrogen .	0·028	0·025	0·073	0·05	0·07	0·02	trace

"In the foregoing analyses the organic matter is not stated alone but along with it is the water which is chemically combined with the mineral constituents, and which is not removed at a temperature of 212° F. Accordingly the organic matter appears more than it really is, but, when compared with ordinary fertile English soils, the quantities, with the exception of No. IV read low, and in some cases extremely so. In every instance the amount of nitrogen is small, and considerably below that found in the average of English agricultural land."

In paragraph 61 the same author says—"I give the following results from an analysis of black cotton-soil by the late Mr. S. A. Hill, and from one which I made of a specimen of this soil from Akola in Berar.

Organic matter and Nitrogen in Black Cotton-soil.

	Black Cotton-soil from North-West Provinces, near the Jumna (S. A. Hill.)	Black Cotton-soil from Akola, Berar (J. A. Voelcker.)
Soil (dried at 212°F.) contained—	Per cent.	Per cent.
Organic matter and combined water	4·95	3·83
Nitrogen	0·034	0·036

"The amounts of nitrogen are very low, and though there is more organic matter than in the soils tabulated in paragraph 58, yet the quantities are not really large. Support is given to my belief as to the condition of this soil, by the increasing practice, among the better cultivators, of manuring it. It was stated in Settlement Reports of the Narbudda Valley some 25 years ago, that it was not the custom to use manure, but now in Saugor and Damoh it is by no means uncommon to find manure used, and the people all say that they want more."

2. Early Experiments and Indigenous Practices.

Under these circumstances it is not surprising that green-manuring was one of the methods of improving the fertility of Indian soils to which the Agricultural Departments first turned their attention. *The Agricultural Ledger*, No. 20 of 1893 and No. 8 of 1897, gives accounts of experiments conducted at Cawnpore, Nagpur and Dumraon, and it is stated that the experiments at Cawnpore had been in progress for about 15 years at the latter date. At Cawnpore also they appear to have been successful in showing a very great increase in the yield of wheat following indigo, either removed or ploughed in. In the latter case the increase amounted to nearly 50 per cent. on an average of 8 years previous to 1893. The experiments at Nagpur and Dumraon were not so conclusive, nor were those with *san* at Cawnpore, but they furnish evidence on the whole favourable to this method of manuring.

These experiments however did little to elucidate the economics of the subject, and there can never have been any doubt that the burial of almost any organic matter in the soil is usually beneficial to succeeding crops. The use of vegetation of all kinds for manure when it could not be turned to any better account has indeed been perfectly familiar to Indian cultivators from time immemorial, and has been variously embodied in agricultural practice. Writing of green-manuring, "a practice," as he says, "not unknown but yet not nearly so widely distributed as it might with advantage be," Dr. Voelcker[1] gives the following account of existing methods :—

"*San* or *tag* hemp (*Crotalaria juncea*) is the crop most generally ploughed in; indigo is another; mustard is occasionally used; and frequently on rice fields the weeds are allowed to grow, and then turned in to act as manure. In Lohardaga the favourite green crop is *sawan* (a wild form of *Panicum miliaceum*) ; it is often grown with rice, and after

[1] Voelcker, J. A. *Report on the Improvement of Indian Agriculture*, pages 106-107.

the rice has been harvested [1] the green crop is turned in and buried in the soil. Green-manuring is well understood in some parts; for example, in Gujarat [2](Bombay). It is also practised in Hoshiarpur, Burdwan, Hooghly, Chota Nagpur, Poona and parts of Khandesh. *San* ploughed in as a green crop, in preparation for sugarcane, is the usual form of green-manuring. In other districts, such as Bareilly (North-West Provinces), green-manuring is quite unknown; in Coimbatore too, so far as the actual growing of green crops is concerned; whilst in many parts of Bengal its use might be more extended. Mr. Moens says of Bareilly, 'The benefit of ploughing in a green crop is quite unknown here.' Experiments made at the Bhadgaon (Bombay) and Cawnpore (North-West Provinces) Farms have demonstrated the advantages of ploughing in green crops such as the *san* hemp or indigo.

'Over a large part of Madras, Coimbatore included, the spreading of wild shrubs such as wild indigo (*Wrightia tinctoria*), *madar* (*Calotropis gigantea*), *avarái* (*Cassia auriculata*), *kolinji* (*Tephrosia purpurea*), convolvulus, and the shoots and leaves of *Pongamia glabra* and other trees is much used on "wet" lands, principally on rice fields. The shrubs and leaves are spread green on the fields, and then trodden in by foot. At Hospet, which is served by a canal led by a weir or anicut

[1] This must have been a misapprehension on Dr. Voelcker's part, the actual practice was thus described by Basu in the year 1890 :—

"The principle of green-manuring is well understood by the people. *Raiyats* like to see a plentiful growth of grasses on their paddy stubble, for grass, as they say, is nothing but manure. They do not, however, wish to see all kinds of grasses growing on the stubble, on account of the difficulty which many of them cause in weeding them out. The most favourite grass which the *raiyat* wishes to see on his dhan lands is *sawan*, the wild form of *Panicum miliaceum*. All other grasses are carefully weeded out in Sravan, but *sawan* is fostered till *bidhali*, when the rice is ploughed and harrowed with a view to destroy the grasses. The *sawan* thus gets easily destroyed, and being decomposed in the soil, gives up its manurial constituents to the growing paddy. The manurial value of *sawan* cannot be much greater than that of other grasses; but its use as a green manure depends on the fact that, unlike other grasses, it gets easily destroyed whenever wanted. In the Five Parganas *raiyats* often grow *sawan* along with sown paddy with a view to restore fertility to any land which is believed to have deteriorated through exhaustion. A few ounces of the seed of *sawan* are sown along with paddy in Jeyat-Asar, and the two crops are allowed to grow till the time for *bidhali* comes in Sravan. By this time the *sawan* has ripened; and the ripe grains are collected if desired by simply shaking the blades. The *bidhali* is then given, by which the *sawan* gets buried in and destroyed. This practice, so far as my enquiry goes is not known in Nagpur, *i.e.*, on the plateau of Chutia Nagpur. Here however a somewhat different method of utilizing *sawan* for manuring *tanr* land exists. *Sawan* is grown for one year, and harvested, after which the long stubble is buried in by a ploughing. The soil thus gets effectively manured, and yields a good crop of *gora* or upland paddy in the next season"—*Report on the Agriculture of the District of Lohardaga* by B. C. Basu, Bengal Secretariat Press, 1890, p. 41.

[2] *Cf.* Leaflet No. 10 of 1912 issued by the Department of Agriculture, Bombay.

from the river Tungabadra, and where the cultivation is exceptionally good, I saw this plan of green-manuring being carried out. Trees are grown round every field and along the banks of water-channels, and are defoliated once in three years; the twigs and leaves are spread on the land where rice is to be sown; canal water is let on, and the twigs are trodden into the soil with the foot. About eight days later, rice is sown broadcast on the top. It is worthy of note that, though served by canal irrigation, the compartments or beds in which the water is enclosed are here quite small, just as in 'garden' cultivation.

"The practice of putting twigs and leaves on rice fields is largely adopted in Tinnevelly.[1] Branches and leaves are used as manure near Bangalore [2] in April, and at the end of the monsoon. When touring in the Suni Valley (Punjab) Dr. Watt pointed out to me a shrub (*Adhatoda Vasica*) which acts as a weed-exterminator; the natives spread it, when green, on their rice fields, and it is said to kill all the weeds in 24 hours. At Mahim the leaves of the sugarcane are spread on the ginger-beds to act as manure; leaves are also put round the plantains. Near Rura (North-West Provinces) I saw a cultivator using leaves as manure on his opium beds, and he thought very highly of them. In the forests of North Kanara and along the Malabar coast leaves are gathered and used as manure. Leaves are, generally speaking, collected in the neighbourhood of towns and villages for the purpose of 'parching' grain.

"I believe that in these various ways of green-manuring the physical improvement of the soil is an important point. At the same time it shows that the value of vegetable matter, as an addition to the soil, is not neglected by the *raiyat*, although some would maintain that its loss in the burning of cowdung is of no account."

The systematic use, for bedding or directly as manure, in South Kanara, of leaves and twigs cut green or collected after falling, is the subject of an article by Couchman in the *Agricultural Journal of India*, Volume III, Part 3 (1908).

The spice gardens in the Kanara district of Bombay depend largely on green leaf manure, the cutting of '*soppu*', or green leaves for manure from '*beta*' lands assigned for the purpose, being recognized as a right of the garden owners. Thus, in 1902, the Government of Bombay, acting on a report by Mollison, directed [3] "that as far as possible there should be

[1] *Cf.* Lonsdale, *Agricultural Journal of India*, Volume IV, Part II, 1909, page 154, where a list is given of leguminous trees so used.

[2] A short list with analyses of the green and dry leaves is given in Bulletin No. 1 of the Mysore Department of Agriculture on *Green-manuring in Mysore* by Coleman and others.

[3] Bombay Government Resolution No. 3203, dated the 9th May 1902.

such an area of forest in each village classed as *beta* as will, together with the assignments already made, constitute an average of nine acres for each acre of garden land," and went on to say—" The garden lands have been assessed on the assumption that enough forest produce was available for their cultivation."

The Forest Department in Madras has from time to time attempted to encourage the growth of trees and shrubs for use in 'wet' lands; and the lopping of pine and other trees for manure in the Himalayas is also the subject of regulations by that Department.

In Trichinopoly, Coimbatore, and other districts in Southern India 'Prickly Pear' is said to be collected in pits and used as manure after rotting.

Similar practices are prevalent all over India. But this bringing in of vegetation from 'jungle' land is not strictly comparable with the growth of a crop for the purpose of green manure, because considerable quantities of fertilizing materials, in addition to the organic matter obtained from the air, are imported in such vegetation. The leaves of a number of trees used for this purpose, specified by Mollison in the report above referred to, were found on analysis to contain, besides a proportion of some 2 per cent. of nitrogen to dry matter, a similar proportion of potash; and the soil to which they were applied was found to be particularly poor in potash. Moreover the feasibility of this method of manuring depends on the supply of materials near to the land to be manured, and of cheap labour for cutting and carrying vegetation of more or less fortuitous occurrence; while with the growth of population, stricter conservation of forest areas, and extension of cultivation, the absolute quantity as well as the relative importance of such waste materials is continually declining. In fact the advance of civilisation is leading in this as in so many other things, to systematization, with resulting great increase of output and efficiency and saving of labour, and we can therefore go on to consider the development of systematic methods.

3. Green-manuring for Plantation Crops.

The early experiments by the Agricultural Departments, did constitute an advance so far as India is concerned, in that they showed by concrete, accessible results how greatly the fertility of a plot of land could be increased by the growth of leguminous crops entirely under the control of the cultivator, without going outside the boundaries of the plot for manure.

But meanwhile, green-manuring had already been adopted in India by European planters, and as the value and perennial nature of plantation crops puts them in a category by themselves, the practice as applied to such crops will be dealt with separately, before considering more recent developments in ordinary agriculture.

So far back as 1890, Mr. Nelson of Arienkow and Lochnagar Estates in Southern India appears to have made systematic experiments in the growth of leguminous crops for manuring coffee, and a pamphlet on the subject published by him in England, was reviewed in the *Tropical Agriculturist* for September 1904 (Volume XXIV). Little detailed practical information seems to have been given in the pamphlet, but the net result is stated by the author in the following words:—"The test that I put legumes to was possibly the severest that could have been tried. I tried them to see if it was possible to bring round Arabian coffee that had almost gone out of bearing through leaf disease. The coffee was so far gone that in many cases the primaries were killed back almost to the stem, and the coffee on the ridges was absolutely bare. The coffee was generally in such a condition that expenditure of any appreciable amount in trying to bring it round would have been considered a waste of money, so as a forlorn hope I tried legumes. With what success is clearly shown by the following figures. The yield the year I began was just over 1 cwt. an acre, requiring 6·25 bushels of parchment coffee to give 1 cwt. of clean coffee; from that the yield gradually increased until I secured a yield of over 7 cwt. per acre, requiring 4·80 bushels parchment to the cwt. This was accomplished by legumes alone, without any other added fertilizer."

A Bulletin [1] by Mann and Hutchinson, published by the Indian Tea Association in 1906, gives a large amount of information as to the practices in vogue in Assam up to that date, and as these practices afford excellent illustrations of the various distinct systems of green-manuring in plantation crops, no excuse seems necessary for quoting extensively from this bulletin.

"The first green manures used for tea by a long way," the authors say, "were undoubtedly leguminous trees of which the 'sau' *Albizzia stipulata* was the earliest and remains to this day probably the best. It was used and recommended in the quite early days of tea in Assam by Colonel Hannay, himself the pioneer planter in Dibrugarh."

Systematic planting of the tree was apparently undertaken because of the observed beneficial effect of such trees on tea bushes growing in

[1] Mann, H. H., and Hutchinson, C.M.—Green-manuring in Tea culture in India. *Indian Tea Association Bulletin No. 2*, 1906.

their neighbourhood. It is not clear whether the effect was attributed originally to the manurial value of their leaves, to the light shade given by the trees, to their influence in opening up the subsoil and draining the land, to their supposed attraction of showers, or to any other of the possible ways in which they might affect the crop. A number of these possibilities are discussed in the bulletin referred to, among these the effect of the leaf deposit occupies a comparatively minor place, and the trees are not lopped or used strictly as 'green' manure. The bringing up of mineral constituents from the subsoil is alluded to, but the nitrogen content only of the dry leaves appears to have been ascertained, and no definite idea of the weight of leaf fall per acre is given.

Finally it is stated that the leaf deposit can only very partially explain the very great and obvious difference in the luxuriance of bushes near the trees. This difference, as measured by the resulting difference in crop, appears, from two experiments conducted in 1902 and 1904 in gardens where both tea and "sau" trees were some 20 years old, to amount to as much as 50 to 100 per cent.

The plate opposite, which formed the frontispiece of the bulletin referred to, gives a good idea of the way in which the "sau" tree is used.

Many other species of Albizzia and other trees are mentioned as used in a similar manner. But, while noting that the trees used are all of the leguminous order and fix nitrogen through the nodules on their roots, the authors appear to consider the chief use of such large trees to lie in the shelter they afford, and in the action of their roots in breaking up clay subsoils and opening up both soil and subsoil to the freer passage of water, thus increasing the root development of the crop. They state that the "sau" trees seem to do more good the older they are and the further their roots penetrate—"little benefit is usually seen till the third year." A distance of 60 feet apart is recommended for planting.

However, a system which does not include the burial in the soil of any green material, cannot strictly be called 'green-manuring,' and the authors go on to consider the growing and lopping of smaller trees or shrubs—a system stated by them to have been recently developed in Ceylon.

With reference to this system the authors quote the following description [1] of the use of the tree *Erythrina lithosperma*. "The thornless *dadap* has been proved to be of great value as a source of organic matter when propagated from cuttings. Cuttings were made, each 5 feet in length and 2 inches in diameter and were put in a clearing along every alternate line at a distance of 4 feet apart. The cuttings were

[1] Wright. *Circulars of the Royal Botanic Garden, Ceylon*, Vol. III, No. 12 (1905).

PLATE II.

Fig. 1.—*Albizzia stipulata*, the *sau* tree of Assam.
Fig. 2.—Tea garden planted with *sau* trees.

(*Reproduced from the Indian Tea Association Bulletin No. 2, 1906.*)

PLATE III.

Boga medeloa, three years old, growing naturally.

(Reproduced from the Indian Tea Association Bulletin No. 2, 1906.)

planted in the wet month of June and regularly lopped every two months. In five months the cuttings gave no less than 4,000 lb. of fresh green material fit to be buried, in ten months 10,200 lb. and in twelve months 15,000 lb. per acre. Other cuttings have been lopped regularly during the last two years, and it would appear possible that in a good free soil about 200,000 lb. of green leaves and twigs per acre can be got from them in that time ......The analyses made by the Government Chemist prove that the leaves and twigs obtained by lopping contain, in a fresh state, 0·852 per cent. of nitrogen, and 4·78 per cent. in the sun-dried material. The leaves which naturally fall from the *dadap* tree have also been proved to contain 1·4 per cent. of nitrogen......The only points to lay stress upon in connection with the use of *dadaps* as green manures are (*a*) that cuttings of the dimensions quoted should be used, (*b*) the cuttings should be planted in holes 1 foot deep, (*c*) planting should be done only in the rainy season, (*d*) if they are used in connection with tea they should be uprooted every year."

As regards this particular tree and its thorny relative (*E. Indica*) Mann and Hutchinson say—"In general so far as light garden soils are concerned, there is not much scope for their introduction, because every advantage obtainable from them can be obtained more easily and more cheaply by the use of the *boga-medeloa* (*Tephrosia candida*)....As there seems a good deal of difficulty in making this latter grow vigorously on heavier land such as the Great Red Bank of the Duars there is a possibility that the thornless *dadap* may have a field for use for such soil."

The use of *Tephrosia candida*, the habit of which is well shown in the illustration opposite taken from the bulletin under reference, is said by the authors to have extended very greatly in Assam. They go on to say—"The advantages of this bush as growing among tea are as follows :—

"(1) It belongs to the leguminous family and the roots are well furnished with root nodules, a sign that it actively fixes the nitrogen of the atmosphere. This is also indicated by the richness in nitrogen of the prunings obtained from growing bushes. A set of such prunings, obtained from three-year old plants and containing an abnormal quantity of woody matter, gave 3·49 per cent. of nitrogen, calculated on the dried material. The actual amount of prunings obtainable per annum from each plant is not yet known, but it is extremely great, and probably approaches that given by Wright as being obtained from the *dadap* in Ceylon.

"(2) It will grow on very poor land, much poorer than that on which either the *sau* tree or the usual annual crops used for green manuring would flourish. This is a particular advantage in many cases in the districts where the tea in cultivation is chiefly on sandy land, and where a previous dose of cattle manure is necessary to get *mati-kalai* to grow.

"(3) The root development is a very deep one, as is indicated by the Plate (opposite) showing the roots of a three-year old *boga-medeloa* plant. This depth of roots has all the advantages claimed for it above when discussing the *sau* tree.

"(4) The surface root development is also good, and as usual improves the tilth of the soil very considerably where it is grown.

"The best way to put this plant out into the tea is probably to plant seeds (generally three seeds in one spot) in the beginning of the rains between alternate rows as follows :—

"Taking 2,000 as the normal number of bushes to the acre this gives 500 as the number of groups of *boga-medeloa* plants.

"Each group of seeds should be protected from injury by three crossed stakes of bamboos, and may then be left to grow for the remainder of that season, practically without special attention.

"In the following cold weather the question of pruning comes up, and three methods have hitherto been adopted.

"(1) There is the original method suggested by Mr. Buckingham, in which each plant is cut down to one to two feet from the ground, three or four times each year, and the prunings buried with the following round of cultivation. This answers very well in some respects, but leads to a bushy plant which interferes with the pluckers getting among the bushes, wets them completely whenever there has been rain, and further, it causes the plants to become badly red-rusted at an early stage of their

PLATE IV.

Root development of *Boga medeloa* showing nodules.

(*Reproduced from the Indian Tea Association Bulletin No. 2, 1906.*)

PLATE V.

Boga medeloa (same plant as in Plate III) with sides pruned off.

(Reproduced from the Indian Tea Association Bulletin No. 2, 1906.)

growth. It seems that if the main stems be cut off repeatedly the plant becomes very susceptible to this disease.

"(2) In this method the bushes are treated as shown in the illustration reproduced opposite which represents a three-year old *boga-medeloa* bush pruned into the form of an umbrella. In this method all the side branches are cut off with an upward sweep of a large pruning knife, and this is repeated at every round of hoeing, the prunings being immediately buried.

"(3) The third system, which we have only seen on one garden, is to allow only one branch to grow on each plant, and cut off several times in the year, if not at each round of the hoe, all side branches whatsoever. We have not had the means of judging the relative value of methods (2) and (3).[1]

"It is never intended that this plant shall occupy the same land for more than three years in succession. By that time it has reached almost as much growth as it will usually obtain, and, according to one of the most frequently adopted methods, should be trenched into the land as a whole. For this purpose trenches are dug in the rows left unoccupied by the *boga-medeloa*, and the latter are then buried in the trenches in the usual fashion. In any case, whether trenching is carried on or not, it is unwise to leave the plants on the same land for more than three to three and a half years.

"Treated in one of the fashions suggested above, the result of the *boga-medeloa* has been extremely satisfactory in many places. The large amount of green matter obtained for hoeing in, without interfering with the regular rounds of cultivation, does a great deal of good in sandy land, improving the tilth and increasing the available plant food.[2] The result has been a vast improvement in much old tea which was formerly thought to be almost beyond redemption, an improvement which will, we believe, be repeated in many cases when the use of the plant is more generally taken up.

"There is one purpose, for which this plant is likely to be valuable, not comprised in its function as a green manure. This is as a mitigator

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[1] More recently Hope and Tunstall, writing in the *Quarterly Journal of the Indian Tea Association,* Part III, 1913, say of these methods :—" The second system has been found to be the most convenient."

[2] On this point Hope and Tunstall say, *loc. cit.*: " Chemical analyses of *boga medeloa* give results which vary very considerably with the age of the plants. The nitrogen content varies from 2-3½ per cent. of the dry matter. The weight of green manure obtained is very difficult to estimate satisfactorily, but it may be considered to be at least 150 maunds of green manure per acre each year, equal in nitrogen content to about 6 maunds of ammonium sulphate."

of the effects of hail. In all our districts the months when hail is liable to do damage to the gardens are April and May. Now if the *boga-medeloa* be planted among the tea and left unpruned for that year until these two dangerous months are passed, if hail occurs it is bound to moderate the damage done by the hail to the bushes, simply because a great deal of the hail will be received by the *boga-medeloa* instead of the tea. We certainly think that the use of this plant is indicated, wherever it will grow, in badly hail-affected districts."

Arhar (*Cajanus indicus*) appears to have been tried by one or two planters in Assam on a system similar to the above, but the results reported do not seem to have been very encouraging.

The third system of green-manuring plantation crops is more akin to that adopted in ordinary agriculture :—a quickly growing annual crop is sown, to be cut and left on, or buried in, the soil before it reaches maturity.

The plant most generally used for this purpose in Assam is *mati kalai* (*Phaseolus mungo* var.). Of this plant the authors of the bulletin say : " the general value and success of *mati kalai* as a green manure seems no longer in doubt. Under average conditions and with ordinary good growth it will give an increase of about ¾ maund of tea per acre." They make the following recommendations as to its use—which, again, are quoted in full as illustrating this system of green-manuring.

1. "The seed should be put into the land, on hoed soil, immediately after the first showers or at the end of April if heavy rain occurs before this, and the seed covered slightly directly afterwards, at a rate of not less than half a maund per acre.

2. " The crop should not occupy the land more than six to eight weeks, and by this time should have grown two feet or more high. During growth the space immediately round the bushes should be kept clean by *khurpying* if possible.

3. " If the plant will not grow without manure, a small dressing of cattle manure, of about one ton per acre, should be put on before the seed is sown. It may also be advisable occasionally to hasten the rapidity of the growth by adding about 5 maunds of oilcake per acre with the seed."

4. " The crop, on hoeing in, should be completely covered with soil, but deeper hoeing than this is unnecessary, provided the block has had the regular deep hoe in the previous cold weather. In a few cases, we have been told that the crop has been left on the land and allowed to die down without special hoeing in, with good results, but we are not prepared to recommend this course in the least."

Other plants, the use of which is discussed in this connection, are *dhaincha* (*Sesbania cannabina*), *Crotalaria striata*, and groundnuts (*Arachis Hypogæa*). Of these, only *dhaincha* appears to be really promising, the *Crotalaria* being too late, and the groundnuts too slow and feeble in habit, to give sufficient bulk to compensate for the injury done to the tea by having to leave the land uncultivated during the period of their growth.

The authors mention also, as plants that have been tried in Assam, *Desmodium polycarpum, Dolichos biflorus* and what is locally called mustard or rape, which latter is recommended when leguminous crops prove, for one reason or another, unsuitable.

Since the publication of this bulletin in 1906, experiments with this system of green-manuring have been continued by the Scientific Department of the Indian Tea Association, and articles [1] by Hope and Tunstall in the Quarterly Journal of that Department discuss the merits of soy-beans, *dhaincha,* and *mati kalai.*

Soy-beans have proved a success in Darjeeling district, where they are sown at the rate of about a maund per acre about the middle of June, sickled when in full bloom (about 3 months later), and hoed in deeply. The authors say of this plant—" the length of time the plant occupies the ground and hence interferes with cultivation may possibly be a drawback, but it is a matter of experiment to determine whether the benefit resulting from its use does not more than compensate for any loss due to the smaller amount of cultivation there may be. Its growth is generally so luxuriant that it chokes a great many weeds, and on stiff soils liable to be damaged by cultivation in wet weather, this crop should be very valuable. On slopes such as occur in the hilly districts its use prevents a great deal of wash."

Experiments in the plains with varieties of this plant are suggested.[2]

Dhaincha is usually sown at the rate of 15 to 30 lb. of seed per acre. As in the case of *mati kalai* the seed is sown at the end of April or beginning of May, when the first showers have moistened the soil, and is hoed in about the beginning of July. It is hoed in much more easily than *mati kalai* because it is not of a twining habit. Both crops appear to provide about 100 maunds of green material per acre under these conditions.

[1] See Part IV, 1912, and Parts I, II, and III, 1913, of the *Quarterly Journal of the Indian Tea Association.*

[2] Several varieties are mentioned by Woodhouse and Taylor in a Memoir on the " Varieties of Soy-beans found in Bengal, Bihar and Orissa." *Memoirs of the Department of Agriculture in India, Botanical Series,* Vol. V, No. 3.

The following passages are quoted at length—though not in their original order—from the articles referred to, as they not only sum up the present position of these particular crops as regards green-manuring, but advocate concisely the use of mineral manures in conjunction with green manures—a practice which universal experience has shown to be one of the most rapidly effective methods of improving poor soils :—

"The supply of organic matter in an ordinary tea garden soil cultivated in the usual manner is rapidly reduced, and one which was originally fertile quickly deteriorates if some effort is not made to replace the organic matter lost. For the maintenance of organic matter *mati kalai* is extremely useful and is the most satisfactory green manure at present known for such a purpose......

"*Mati kalai* will not however grow satisfactorily on a poor soil without manure......

"*Dhaincha* seems to thrive best on a sandy soil, and will grow without manure on much poorer soils than *mati kalai*......

"Experiments with annual applications of *dhaincha* and *mati kalai* at the Heeleaka experimental station gave the following results :—

Plot	1st year	2nd year	Total	
No manure	4·67	5·42	10·09	Maunds of tea per acre.
Dhaincha	5·15	5·76	10·91	
Mati kalai	5·02	5·75	10·77	

"From these figures it would appear that *dhaincha* was the better manure, but those following show that when the poor soil had been improved by the continued application of the green manure, the *mati kalai* proved its superiority :—

Plot	3rd year	4th year	5th year	Total for 5 years	
Dhaincha	6·07	5·58	6·38	28·94	Maunds of tea per acre.
Mati kalai	6·43	6·73	8·20	32·13	

"It must be remembered that the primary consideration of a green manure crop is quantity. Figures as to the amount of nitrogen fixed per acre are very misleading and are of little use in formulating a manure programme. The great question when choosing a green manure crop is which plant will give the greatest amount of organic matter on the particular soil under treatment............

"The second aim of green-manuring is to enrich the soil in respect of nitrogen. Only certain leguminous plants are capable of doing this for they alone have the root nodules which harbour the species of bacteria which actually promote the fixation of nitrogen.............................. Consequently serving as they do a double purpose, that of supplying organic matter and nitrogen, leguminous plants chiefly are used as green crops.

"In some cases, however, the soil may be too poor to provide other constituents necessary to the plant such as potash, phosphates, etc., and a poor crop only is obtained and no opportunity is afforded of enriching the soil to any extent in respect of nitrogen.

"An excellent opportunity is here afforded for the skilful use of manures. Treating the soil with manure containing potash or phosphates, and no nitrogen, for the purpose of enriching the soil in respect of nitrogen, may be a new idea to many, particularly to those whose only idea of manuring is to apply periodically the amount of nitrogen, phosphoric acid, and potash which they calculate has been removed by the bushes since the previous application; but the manuring of green crops, and especially of such as are leguminous, is an extremely sound method of promoting fertility of the soil. It is often the case that a soil is so poor in organic matter and its fertility so reduced that green manures will not grow, and often when we have had occasion to enquire whether green-manuring has been carried out on gardens, we have been informed that attempts to do so have ended in failure, though in many cases the desirability of replenishing the supply of organic matter has been fully recognized—in fact the failure of the green crop itself points to the infertile condition of the soil. In such cases manuring of the green crop should be carried out. A two-fold benefit is derived from the use of artificial manures in conjunction with green crops. In the first place the growth of the latter is assisted, and if it be a leguminous crop the fixation of nitrogen is also affected favourably if the manures used supply readily available potash and phosphates. There is also the reciprocal action of the green crop on the manure. The growth of a green crop tends to accelerate the decomposition of certain manures such as basic slag, bones, etc., and it is, therefore, an advantage to grow a green crop on the land on which such manures are being used. The plant takes up a certain percentage of the material provided by the manure and when the crop is hoed in, this again becomes available to the bush within a short time. When soluble manures are applied to a green crop the latter makes use of them, returning them to the soil again as it decomposes and thus preventing the waste which would occur if soluble

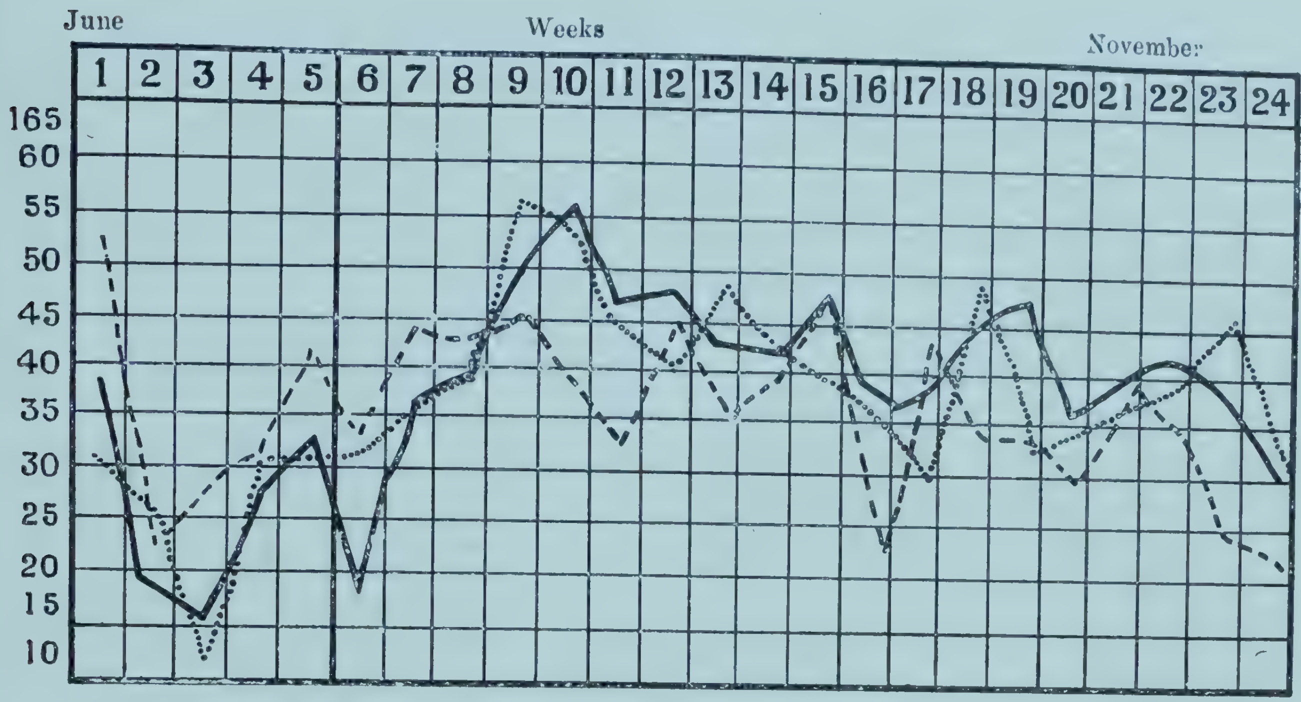
manures had been employed without a green crop, when they would have run a great risk of being removed by rain. The nett result, therefore, of manuring in this way, is to produce a heavier crop, and, in the case of leguminous crops, to promote a greater fixation of nitrogen. It also has the result that the availability of both soluble and insoluble manures is increased.

"The actual choice of manures for this purpose should depend upon circumstances. If the production of a large amount of organic matter or of fixation of nitrogen be of the greatest importance the manures should be chosen entirely to promote the production of a big crop. In the first instance nitrogenous manures in general should be applied, for they produce rapid growths of tissues and development of shoots and leaves, consequently a bigger crop is obtained; though other manures should also be used if the particular soil is known to require them. An example in illustration of the use of manures to promote the fixation of nitrogen was afforded at Heeleaka where a noticeable increase in a crop *mati kalai* was effected by the addition of potash to a mixture of manures. The efficacy of potash for this purpose has been observed in many countries under many conditions and in the case of different crops.

"If on the other hand an all-round scheme of treatment of the tea is being taken in hand, including the use of manures and occasional growth of a green crop, the manures could be chosen without reference to the requirements of a green crop, but advantage should be taken of their application to grow a green crop in conjunction with them.

"A general characteristic of green manures, probably to some extent due to the removal of moisture from the soil, is demonstrated in the accompanying diagram. Observation shows that the early showers only moisten the surface layers, soil three or four inches below being comparatively dry. The roots of the green manure plants absorb most of this surface moisture and prevent it reaching the tea roots. Hence the flushing is retarded. Various suggestions have been from to time time brought forward to remedy this. One way is by planting later in the season when the ground is thoroughly wetted. There are, however, serious objections to this. Firstly, labour is required when it can be ill spared; secondly, the young plants are much more liable to be attacked by disease. Excessive moisture in the early part of this season caused a number of *dhaincha* crops to fail. A better method, which overcomes most difficulties, is by sowing the crop in alternate rows over the trenches in which the prunings have been buried during the prevoius cold weather. The roots of the green crop then confine themselves to the trenches and do not interfere so seriously with the water supply, and

besides developing more nodules the plants are generally stronger and more healthy."



Check ------- Mati-kalai .... Dhaincha ————

The thick vertical line shows the date the crops were hoed in.

Letters and articles have from time to time been published by individual planters who have made a success of green-manuring.

In particular, Mr. Claud Bald, Manager of the Tukvar Co., has for many years taken a keen interest in both the practical and scientific aspects. In an article in the *Agricultural Journal of India,* Vol. VIII, Part II, he shows that he has found green-manuring both the cheapest and best method of manuring tea in Darjeeling where the prices of imported manures are very high. In the case he quotes, the green crop was sickled when mature, and left on the surface of the ground until the end of the rains, when it could be dug in without fear of losing soil through 'wash.'

Since Mr. Nelson's experiments in 1890 mentioned above, few systematic experiments on green-manuring seem to have been made by South Indian Planters.

In the *Planters' Chronicle* for October 8th, 1910, Mr. R. D. Anstead, Scientific Officer of the United Planters' Association of Southern India, mentioned an experiment in the establishment of leguminous weeds among tea in the Wynaad by the simple process of having all other weeds removed. In the issue of September 2nd, 1911, it is stated that,

as a result, a cutting of *Tephrosia tinctoria* was made from an area of six square feet, which yielded at the rate of 7½ tons of dry matter, containing 262 lb. of nitrogen, per acre. Making all due allowance for the 'marginal effect' in the case of so small an area, this would seem to indicate great possibilities. The experiment was however not persisted in, owing to a change of management of the estate.

In Coorg good results have been obtained on Ceara rubber by burying prunings of *Crotalaria striata* for three years in succession.

Cassia hirsuta was said by Mr. H. M. Mann in 1911 to be the most easily grown and hardiest of any cover crops among thin coffee on his estate near Sidapur in Coorg. He also considered that it gave the largest quantity of green mulch.

Sesbanias have also been tried among coffee in South India, but no definite results appear to have been recorded.

In addition to the above information, culled from the *Planters' Chronicle*, Mr. Anstead has published in that paper numerous analyses of plants that have been tried or suggested as green manures, as well as scientific articles advocating the practice and quoting the results obtained in other countries. He has also kindly furnished the writer with the following note which is a welcome supplement to the somewhat meagre supply of published information regarding green-manuring as actually practised on Southern India plantations.

Note on Green-Manuring in Planting Districts, by R. D. Anstead, Planting Expert.

Coffee.—

Coffee is planted under shade and so closely that the bushes soon close in and prevent the growing of green dressings. In young clearings, however, green dressing crops have proved a valuable aid to the growth of the coffee and in some districts are used to a considerable extent. In open spaces in old coffee there is also an opportunity for green dressings which is taken advantage of by many planters.

The principal plants used for the purpose are *Crotalaria striata, Crotalaria heptaphylla, Cassia mimosoides, Indigofera tinctoria, Tephrosia purpurea, and Cassia hirsuta.*

As an example of the benefit to be obtained from the use of green dressings in coffee the following case may be quoted, reported by the Scientific Assistant in Mysore :—

"Fifteen acres of old coffee were collar pruned in 1910, the shade was cut out and the land round the coffee stumps forked. Young shade

was planted and, in April 1911, *Cassia occidentalis* was sown. By August of the same year this green dressing had grown to such a height as to smother the coffee completely. It was then cut down and forked in. An enormous improvement in the coffee was noticed and it made wood rapidly. In 1911-12 it gave a crop of four cwt. per acre, a remarkable yield considering that two years previously it had been cut down within six inches of the ground."

Tea.—

With tea the advantages to be derived from the use of green dressings are rapidly being realized. This form of manuring costs less for the results obtained than the use of artificial manures.

Two forms of green dressing are used—

(*a*) A tree which is planted widely apart and forms a light shade for the tea and which is lopped at the end of the rains or the beginning of the dry weather. The loppings are spread on the ground between the rows of tea, with the double object of retaining as much of the soil moisture as possible for the use of the tea in the dry weather (by checking the supply absorbed by the green dressing), and of providing a mulch on the soil surface to aid the conservation of soil moisture. The plants generally used for this purpose are *Erythrina lithosperma, Albizzia stipulata*, and *Albizzia moluccana*.

(*b*) A green dressing crop, proper, grown between the rows of tea (especially when it is pruned), and cut down and dug in before the hot weather. For this purpose the following plants have been found useful, *Tephrosia tinctoria, Atylosia candollei, Crotalaria striata, Sesbania aculeata*, and *Sesbania aegyptiaca.*

Rubber.—

Much of the Hevea Rubber in South India has been grown by the aid of green dressings. A common practice is to plant *Erythrina lithosperma* between the rows of Rubber, and alternately lop it and bend it over till it forms a complete cover, keeping down the growth of all weeds and forming a heavy mulch on the ground. As the Rubber grows and closes in, its shade gradually kills the Erythrina; and when this begins to happen the green dressing is jacked out, roots and all, and burned.

Other crops which have been used and cut at the beginning of the dry weather and used as a mulch and afterwards dug in are *Cassia mimosoides, Crotalaria striata*, and *Tephrosia purpurea.*

PART II.

GREEN-MANURING IN GENERAL AGRICULTURE—RECENT DEVELOPMENTS.

1. General.

Having seen, then, that the practice of green-manuring is not unfamiliar to Indian cultivators and that the systematic use of green manures by European planters in India probably preceded the first experiments tried under Government auspices, and has now become general, we can go on to consider the question of green-manuring in ordinary agriculture, the investigation of which has devolved almost entirely on the Agricultural Department.

The early experiments at Cawnpore, Nagpur, and Dumraon have already been referred to (page 5) ; they may be said to have established the potential value of green-manuring over a wide area, leaving the rationale of the practice for further economic and scientific differentiation with respect to varying conditions of soil and climate.

Only with the expansion of the Agricultural Departments in 1905, were opportunities for such further investigations at all considerably multiplied, and it may seem early to attempt any survey of the results arrived at. Field experiments have however since been carried out at several stations in almost every Province in India, and important laboratory investigations have been conducted in Madras and Assam as well as at Pusa; and in view of the striking practical success achieved in some districts and the economic importance of the subject to India as a whole, a preliminary survey of the progress made may be of some utility.

Limiting Conditions.

Yet if such a survey of the results obtained in the necessarily scattered centres of investigation is to have any general utility, some kind of generalization and classification is essential ; and fortunately some generalization is in this case made possible by the incidence almost all over India of a marked hot dry period (of longer or shorter duration) during which little growth takes place in the absence of costly irrigation, while the mere rotting of green manure requires either a large quantity of water or a smaller amount of moisture for a considerable time after the crop has been ploughed in.

If the drought that prevails for half the year over the greater part of India necessitates constant cultivation, and so depletes the soil of

organic matter, on the other hand the moist heat of the monsoon, given sufficient water from rain or irrigation, promotes a tropical luxuriance of vegetation which might be expected to redress the balance. That it does not do so appears to be due principally to three causes:—

(1) The use for fuel of all spare organic matter, including cattle dung and as much as is not required for fodder of the stems of such crops as occupy the ground for the whole of the monsoon season.[1]

(2) Insufficiency of rainfall in many districts, which precludes the profitable cultivation of both a full monsoon crop and a cold weather crop on the same land.

(3) The growth, for food purposes, of crops like rice which yield a relatively small proportion of straw to grain, and while occupying the ground for part only of the monsoon, yet leave insufficient time, during the remainder, for a second crop to mature; with the result that the ground is frequently left fallow or uncultivated.

As regards the first of these considerations, no doubt the direct substitution of green-manuring crops for coarse fodder and fuel crops is impracticable; for, to the extent that the whole monsoon period is now utilized for the growth of crops for which there is a direct demand for economic purposes, it is clearly unlikely to be economical to substitute a crop the use of which is merely to improve the land for the growth of another crop. A suitable rotation of crops of direct economic value must almost always be the prime consideration.

But such a rotation usually includes crops which do not utilize the whole of the monsoon period. Moreover the development of other kinds of fuel must tend to decrease the amount of agricultural produce used as fuel, while improved methods of storing coarse fodder crops will make it possible to consume a greater part of the whole produce of such crops as fodder; and these developments will combine to lessen the area on which such coarse crops are grown and will increase the importance of the relatively valuable seed crops which do not provide any great excess of organic matter and the growth of which does not utilize the whole of the monsoon period, nor always require the conservation of the whole of the monsoon rainfall.

The considerations referred to under (2) and (3) may thus be regarded as those which generally condition the supply of the marginal surplus of organic matter in ordinary Indian agriculture. On the one hand, due regard to the production of crops with the maximum of economy

[1] In parts of Bombay Sunn hemp or *tag* is grown primarily for fuel *cf.* Patil, Bulletin No. 47 of 1911, published by the Department of Agriculture, Bombay.

commonly[1] precludes the use of the whole of the monsoon period for the growth of a single crop in every successive year in the rotation, while on the other hand the remainder available, of the monsoon period, is too short for the production of a second mature crop.

Under favourable conditions agriculturists would use such an interval for the growth of a catch crop for fodder purposes; but there is in many districts a surplus of fodder in the middle of the monsoon and the crops which grow most rapidly at that time do not lend themselves to any practicable method of curing, whereas the slower-growing crops hardly produce, in the time available, enough bulk to be worth curing.

There is thus usually in the rotation a shorter or longer period of the monsoon during which the land is uncropped, and is either left to grow a partial crop of weeds, or, if necessary for the benefit of the succeeding crop, is kept cultivated as a bare fallow.

It seems to be, as a rule, this fact which gives an opening for the economical use of green manures. It has been found possible, given early sowing, to grow, even on land exhausted by continuous cropping, a considerable bulk of green crop of certain plants—chiefly of the leguminous order—even by the end of the first month of the monsoon, leaving time for the rotting of the crop for manure after ploughing in; and enabling the remainder of the monsoon to be used for the growth of one of the more valuable later monsoon crops, or for the accumulation of moisture in the land for the succeeding cold weather crop. On the other hand the actual substitution of a green-manure crop for one of primary importance can hardly be economical except in the interests of a specially valuable crop and in the absence of more economical manures.

The advantages of green-manuring thus depending, as a rule, on the utilization of a shorter or longer period of the monsoon during which the ground might otherwise be uncovered, it is convenient to classify the various systems of green-manuring according to the length of this period, that is according to the time of sowing or planting the main crop for which the green-manuring is regarded as a preparation.

Classification.

Classified on this principle such crops fall into four groups:—

1. Main crop rice, transplanted when the monsoon is fairly established—usually about six weeks after the first monsoon showers.

[1] Cotton is a conspicuous exception to this generalization and there appears to be little prospect of an extension of green-manuring in unirrigated cotton tracts.

2. Crops (like tobacco in Bihar) which are planted at the end of the monsoon, and the cultivation necessary for which precludes the maturing of a monsoon crop; and valuable cold weather crops which require the conservation of a considerable part of the monsoon rainfall for the production of a full yield.

3. Sugarcane, jute, and garden crops which are sown at the beginning of the hot weather and the value of which gives them a peculiar position as regards manuring.

4. Other crops grown on irrigated land and which are thus to some extent independent of the monsoon.

2. Rice.

The most important recent development of green-manuring in India has been in connection with the rice crop.

Experience has shown that the most economical way of growing the main crop of rice is usually to sow the seed in a seed bed and to transplant the seedlings into puddled land when sufficient water has accumulated. This method is almost universal in India, and is being rapidly adopted in the few backward tracts where it is not already prevalent.

Experiments in some of the principal rice-growing tracts of India have proved that the interval between the first monsoon showers and the transplanting of the seedlings can be profitably utilized for the growth of a green manure crop. Under favourable conditions the seed of the green manure crop may even be sown at the end of the preceding cold weather and the young crop will survive the hot weather and be ready to take full advantage of the early part of the monsoon.

Madras.

In parts of Madras, where the green-manuring of paddy has perhaps been spread more than in any other province by the Agricultural Department, this system is a development of one previously pursued by the cultivators, and which is thus described by a special Correspondent in the *Madras Mail* of April 20th, 1908 :—

"On a large part of the wet land in the Kistna and Godavari deltas, the seed of sunn-hemp (*Crotalaria juncea,* Tamil, *Sanappu*; Telugu, *Zanumu*) is sown partly for fodder and partly for manure, amidst the ripe paddy crop, about 15 or 20 days before it is reaped.* The sunn-hemp grows for about three months, when the succulent upper portions are reaped for fodder and the rest added to the soil as manure."

* November-December.

Wood, in the Scientific Report of the Samalkota Agricultural Station for 1908-09 says—"A hot weather tour was made by the Deputy Director through the Delta in June, just before the monsoon was due, to ascertain the extent to which green-manuring is carried out. It was found that the practice varied from taluk to taluk and was naturally most common in those lands where the irrigation supply for the second crop was most assured. The cultivation of a legume after first crop paddy is excellent practice, and could be extended. The crops sown are generally sunn-hemp, black gram (*Phaseolus mungo* var. *radiatus*), green gram (*Phaseolus mungo*) and horsegram (*Dolichos biflorus*). The first of these, sunn-hemp, is sown only after a long season paddy, as if sown much before the middle of December, climatic conditions are not favourable for it. A broad-leafed variety of green gram with a more procumbent habit is sometimes sown with irrigation water or after 'mango' showers in April and May, on paddy lands, and is trampled in when the land is puddled for the paddy crop. No seed is formed when the crop is grown in this way, and the delta supply of seed is obtained from cold weather crops, grown on the islands in the Godavari (*lankas*) or in the uplands." A series of experiments was accordingly started on the Samalkota Farm—accounts of which are to be found in the annual *Scientific Reports* of the station for 1908-1914. At first an attempt was made to grow second-crop [1] paddy after sunn-hemp; but the growth of *san* proving to be frequently almost negligible the practice of second cropping was given up and "*dhaincha*" (*Sesbania aculeata*), *teegapesalu* (*Phaseolus mungo* var.) and sunn-hemp were allowed to stand over the hot weather, to be puddled in for the main paddy crop in June-July. The sunn-hemp failed, and since then the experiment has been continued with the sesbania and phaseolus. Large yields of paddy are obtained, but it is not clear that, given sufficient water, the loss of the second crop would be compensated for by the manure, or that it would not pay better to grow a crop that could be used as fodder, leaving the residues only to be ploughed in. Indeed it seems probable that the original local practice was largely based on the value of a leguminous fodder crop at this season.

The greatest development of the practice of green-manuring in Madras has however taken place in the extreme south. An interesting paper on paddy cultivation in the Tinnevelly District was published by Lonsdale in the *Agricultural Journal of India*, Volume IV, Part II, and reprinted as a bulletin (No. 61) by the Madras Department of Agriculture in 1909. The main or *pishanum* crop in the extreme south is harvested in February, March or April, and the second or *kar* crop in July, and

[1] The seed for this crop is sown in January and transplanted a month later.

the bulletin gives the following account of the use of *kolinji* (*Tephrosia purpurea*) as a green manure for the main crop :—

"The seed is gathered from the waste lands when ripe about the month of July. Coolies are paid one measure of paddy for one measure of thrashed *kolinji* seed. It is then kept in a dry place and occasionally dried in the sun till *pishanum* paddy is harvested in February, March, or April. As soon as possible after a plot has been harvested the land is ploughed once and if the soil is hard it is cross-ploughed also. If the soil is so dry and hard as to prevent ploughing immediately after harvest, then every opportunity is taken of ploughing after the showers of rain which usually fall in April and May, but the earlier the land is ploughed and the seed sown, the better will be the germination. Three to five heaped Madras measures are then sown broadcast, per acre, and the seed is covered by ploughing once and cross-ploughing with a light wooden plough. No further cultivation is necessary at this stage. It must not be irrigated. The crop is allowed to grow till August or September when every opportunity should be taken of ploughing once through the crop in the dry state (after the showers of rain which usually fall during these months) in order that weeds may be destroyed and the soil aerated. *Kolinji* is deep-rooted, consequently very little of it is uprooted by the plough, and the uninjured plants will grow much better and seeds previously buried too deep and too shallow will germinate. In October irrigation-water becomes available, the plots of *kolinji* are then flooded and ploughed in puddle. If the *kolinji* is very thick and the plants tall it is advisable, after flooding but before ploughing, to pull the *kolinji* up by the roots and spread evenly over the plot. It is then easily trampled in by ploughmen and cattle whilst puddling. Thus by spending about 6 annas on seed and doing a little extra labour in the dry season when the work on the farm is slack, a saving of 10 to 15 rupees per acre for *poonac* or jungle leaves can be made, and often a great deal of time is saved, and all big ryots know how important it is not to be late in the transplanting of paddy. *Kolinji* grows best in light loamy soils. It does not thrive well in stiff clays or land which is water-logged."

A simpler method of cultivation is described by Sampson in the *Madras Agricultural Calendar* for 1912-13 :—

"The seed is sown a week or fortnight before the harvest of the paddy crop, *i.e.*, before the lands are left idle after removing the paddy crop. If the seed once germinates the crop is practically assured though it may suffer if the drainage is bad and if starving cattle are allowed to graze on the fields where it is grown. Ordinarily cattle will not eat it, though complaints have been received from the Tanjore delta that cattle

have damaged the crop. The crop has the advantage therefore of requiring little cultivation, of being extremely drought-resistant and of not being relished by cattle."

The seed rate for *kolinji* is about 17 lb. per acre.

Sampson also says :—" Indigo behaves in much the same way as Wild Indigo, only it has the advantage that it can be cut and the crop will sprout again. Thus in Tanjore a cutting is often taken for the purpose of manuring seed-beds, and the crop which is left sprouts again and can be ploughed in as green manure."

Dhaincha appears to have been found superior to *kolinji* under some conditions. The following is the substance of the recommendations made by Sampson in the Madras Department leaflets Nos. 10 of 1910 and 1911 :—*Takka poondu* (*dhaincha*) answers the description of an ideal green-manuring crop better than any other which the Department has tried. It can withstand severe drought and will also grow on badly drained land and on land which is slightly saline. If there is sufficient moisture to germinate the seed, the crop does not require any irrigation. It can be ploughed in within 3 months, or it can be left on the ground, where it will continue to grow for 5 or 6 months, and cattle do not care for it when grown up. Thus it is very useful on uncertain double crop lands. If there is sufficient water for a first crop it can be ploughed in, if there is not, it can be left to grow until the season for planting the second crop. *Takka poondu* was grown on an acre of poor, badly drained and slightly saline land, which gave a yield of 924 lb. of paddy per acre the year before. The land was ploughed after the paddy was harvested in February and the seed of the *takka poondu* was sown broadcast, being covered by a second plough. The crop was ploughed in in June, being then 5 to 8 feet high. The yield of paddy obtained was 2,086 lb. per acre. The cost of growing the green manure was Rs. 6-11-2 per acre, while the value of the increase in the paddy crop was (at 10 Madras measures per rupee) Rs. 46-6-0 per acre. The best results have been obtained by ploughing the land after paddy harvest, by sowing the seed broadcast and covering with a light ploughing. If there is sufficient moisture in the soil to germinate the seed (either the moisture left in the ground after the paddy harvest, or applied by a light irrigation or by a sowing rain), the crop requires no further attention except to keep off goats and cattle. As long as the plants are seen 1 to 2 feet apart, the germination can be considered satisfactory as these plants will soon grow up and cover the ground, while other seed which has not germinated will come up with the next rain. If grown a second year on the same land, *dhaincha* grows much more luxuriantly

than in the first year. The local variety of *takka poondu* is slightly hardier than the Bengal variety; the plant is also slightly thorny, which renders it more unpalatable to cattle, and it has a smaller seed.

In leaflet No. 18 of 1911 it is stated by Wood that the seed may be sown in the standing crop of paddy just after the last irrigation and about a fortnight before harvest, but if water is available after harvest, ploughing and sowing then is recommended, and no charge is made for the use of Government water for the irrigation.

Harrison in the *Madras Agricultural Calendar* for 1911 says that under favourable circumstances a crop of *dhaincha* will weigh about 20,000 lb. per acre and contain about 125 lb. of nitrogen.

The seed rate for *dhaincha* is from 10 to 20 lb. per acre according to circumstances.

Kolinji and *dhaincha* are purely green manure crops, being practically useless for any other purpose. In the leaflet referred to above Wood goes on to say: "Both these are long growing crops, and can only be used in single crop lands; where the land is double-cropped and the interval short, sunn-hemp is recommended. This crop matures in 60-80 days, and if left much beyond that, will deteriorate. Advantage may be taken of the moisture left in the ground after the paddy crop, or of early showers, to sow it about two months before the time puddling is expected to begin. Even this may be sown without ploughing, but to ensure the full benefit of the treatment, it is better to cover the seed by a single ploughing. Sunn-hemp has also been tried after paddy on single-crop lands, being then sown in the standing crop. When it is mature, that is when the flowers are just beginning to form, it may be cut for fodder leaving about a foot of stalk on the ground. The fodder should be slightly wilted before use, or may be made into hay, mixed with paddy straw or Bengal gram husk and makes an excellent and nutritious food, at a time when grass is becoming scarce. The butts, if showers are received, sprout afresh and in good seasons may yield 30-40 headloads of green stuff to be trampled in."

Sampson says in the Madras Department of Agriculture leaflet No. 10 of 1910: "Sunn-hemp will grow in 2 months to a height of 4 to 5 feet. A very poor field, which the year before gave a yield of 904 lb. per acre, gave the next year a yield of 1,584 lb. per acre, after a crop of sunn-hemp had been ploughed in. The green-manure crop costs Rs. 7-4-8 per acre to grow, and the increased value of the paddy crop at 10 Madras measures per rupee was Rs. 27-4-0."

In his paper referred to above Lonsdale gives an instance of a crop of sunn-hemp sown on September 1st, 1906, which was ploughed in when

7 weeks old, with the result that the land,—which had never been known to give more than 700 Madras measures (2,000 lb.) per acre of paddy before,—gave 1,225 Madras measures (3,400 lb.) per acre from the following crop.

On the other hand, on the heavy delta soils at Manganallur the application of a green manure crop in the ordinary way resulted in a failure of the paddy in that year. No further manure was given, in anticipation of reaping the benefit in the following year. The following table taken from the *Annual Report of the Madras Department of Agriculture*, 1913-14, shows the result.

Paddy yield per acre in pounds.

Field No.	1911-12	1912-13	1913-14
	Treated in the ordinary method prevailing in Tanjore	Green-manure applied, crop failed	No further manure added
	lb.	lb.	lb.
1	1,149	205	2,251
2	1,066	164	2,332
3	1,206	253	1,963

Sampson[1] has suggested that the failure was due to the green manure interfering with the drainage of the soil, and further work to elucidate the point is in progress. In connection with this, the scientific work done by Harrison and Aiyer at Coimbatore, and referred to again below (p. 53) is of interest. In the 2nd part of their paper[2] on the gases of swamp rice soils, published in 1913, the results are thus summarized :—

"These investigations have led the authors to the conclusion that the surface film of algæ, etc., which covers the surface of swamp paddy soils, and which evolves large quantities of oxygen, is the chief agent in causing the aeration of the roots of the crop.

"The oxygen evolved by this film is dissolved in the irrigation water and thus produces a very highly aerated solution, from which the roots

[1] *Report on the experimental work of the Manganallur Agricultural Station*, 1912-13, page 5.

[2] The Gases of Swamp Rice Soils, Part I. *Memoirs of the Department of Agriculture in India, Chemical Series*, Vol. III, No. 3.

derive the oxygen essential for them. In undrained soils, this solution does not penetrate into the soil, and, consequently, the roots are congested near the surface of the soil, and the amount of soil from which they derive their food is therefore limited, and the crop suffers. In drained soils this strongly aerated water penetrates the soil, and the roots are able to penetrate to a greater depth. The mass of soil from which the food supply is drawn is increased, and the crop benefits in proportion.

"Too great a rate of drainage decreases the formation of the film and the aeration of the roots is thereby lessened. There is therefore for all swamp paddy soils an optimum rate of drainage which produces the greatest aeration and this rate of drainage is a comparatively slow one.

"Aeration of these soils by atmospheric oxygen is not as effective in promoting root aeration as is aeration by the water draining through them.

"The use of green-manures in drained paddy soils induces a greater activity on the part of the surface film, thus leading to a better aeration of the roots."

The important practical conclusion is also drawn, that:—

"The practice of green-manuring, so general in South India, is, therefore, quite sound in principle so long as there is drainage present in the soil. It is only when the drainage is deficient that the toxins produced during the fermentations are able to affect the growth of the crop detrimentally, and under these conditions, the green-manuring should only be undertaken after careful consideration and even then with great circumspection."

However, the general effectiveness of these methods of green-manuring is undoubted; what is not so satisfactorily established is the cost of the process.

Wood says [1]:—

"The cost of such green manure crops depends on the amount of cultivation necessary. Where the seed is simply thrown on the surface, the cost is simply the value of the seed or the trouble of collecting it, but generally the cost may be put at from Rs. 2 to Rs. 6 per acre."

Harrison says [2]:—

"The nitrogen contained in mineral manures costs from 9 to 11 annas per lb. and that in *poonacs* about 8 to 8½ annas. On the other hand the nitrogen contained in a green manure is obtained solely at the expense

[1] *Madras Department of Agriculture leaflet* No. 18 of 1911.
[2] *Madras Agricultural Calendar*, 1912-13 and 1913-14.

of small cultivation charges, and costs not more than one anna per lb. and more often much less than this."[1]

But that there is much to be learnt even in Madras as regards the economic aspect of green-manuring is evident from the experience at Samalkota where experiments have, as mentioned above, been in progress since 1909 under consistent management. In the *Administrative Report*[2] *of the Samalkota Agricultural Station* of 1913-14 Hilson says:—
"Regarding the question of lodging, conditions were very favourable this year, and as far as weather conditions were concerned the crop had no excuse for lodging. It was however noticeable that on all the plots which had received green manure this year the crop lodged, while on those which were not manured the crop stood till harvest.

"The effect of the heavy dressings of green manure has been to increase the growth of straw considerably as will be seen from the results obtained from fields Nos. 10 and 11 and 17 and 18.

Field No. 10...........	3,245 lb. of straw per acre.	Rasangi.
„ No. 11..	4,982 „ „	

[1] These statements no doubt correctly represent the case when *kolinji* and *dhaincha* or other such hardy leguminous plants are sown on land which is not in a condition to carry any crop of direct money value, and the possibilities of extension of green-manuring indeed probably depend largely on the fact that the struggle for survival under severe climatic conditions has resulted in the evolution of a large number of hardy, unpalatable, deep-rooting leguminous plants. But where better growing conditions can be secured such as are necessary for the more tender plants sometimes used as green manure, there is always the question whether it would not pay better to modify the rotation so as to increase the proportion of leguminous crops grown, and to use them as fodder instead of solely as green manure. The cost of green-manuring in such cases is represented by the value for any other purpose of the most paying crop that can be grown. (*cf.* Roberts—Green-manuring and hot weather cultivation in the Punjab. *Agricultural Journal of India*, Vol. VIII, Part IV, October, 1913). Coleman in his bulletin on green-manuring in Mysore, previously referred to (p. 7) which gives a very large amount of useful information on the subject, reads a homily to the cultivator who 'cannot resist the temptation of gathering a crop which is ready to harvest,' but the onus of proof would appear to lie on those who deny that this is the best way of utilizing a crop that can be matured in the time available, and the compiler is inclined to suggest that, failing evidence to the contrary, the fundamental maxims which practical farmers may safely follow in the matter of green-manuring are:—

(*i*) Never miss an opportunity of early sowing of a hardy quick-growing leguminous crop if even a month of suitable moisture conditions, during which the land would otherwise be vacant, occurs in the rotation, provided that a sufficient supply of moisture for the succeeding crop can be counted on.

(*ii*) Never plough in a crop without considering its value for other purposes.

(*iii*) In reckoning the cost of any crop that it is proposed to sow for green-manuring only, consider the value of the most profitable alternative crop.

[2] *Report on the operations of the Department of Agriculture, Madras Presidency,* 1913-14, pp. 26-27.

Field No. 17...........	6,324 lb. of straw per acre.		Konamani.
„ No. 18	4,062	„ „	

" Fields Nos. 11 and 17 were green-manured with *teegapesalu.*

" The same effect is to be noticed from the application of paddy straw—

Complete manure ....4,250 lb. of straw per acre.

Complete manure *plus* 5 tons paddy straw per acre............6,330 „ „ „ „

" The beneficial effect of a heavy dressing of 2,000 lb. of green manure on a sticky field is marked, but after the condition of such a field has been ameliorated it is not advisable to continue to apply the manure so heavily, as there is always risk of bad weather at flowering time which, if the crop is luxuriant, will cause it to lodge, and much of the grain will be empty.

" How much and at what intervals, green manure should be applied is a question for experiment, the answer to which will vary greatly with the kind of land and previous treatment."

It is clear that there is much to be said for the original local practice of feeding a leguminous crop off, and experiments have been designed to ascertain to what extent crops can be grown for the dual purpose of forage and green manure.

Meanwhile however green-manuring is being widely extended in the Presidency, and the compiler is indebted to Mr. D. T. Chadwick, the Director of Agriculture, for the following summary of the situation at the end of 1914 ;—" It has been another year of development. Over 158,000 lb. of green-manure seeds were sold by the Department, independent of private sales. We have now regular contracts with people for the supply of these seeds by the 50,000 lb. and over. The practice of green-manuring is mostly confined to rice lands, and in certain parts is valued by the ryots as worth Rs. 15 and upwards an acre. It does not cost more than Rs. 4 to raise a crop of green manure. The spread has been greatest in the extreme south, *viz.,* Tinnevelly, Madura (under the Periyar), South Arcot, Chingleput and to a lesser degree Trichinopoly, Coimbatore and Chittoor."

In no other Province has the practice of green manuring paddy spread to anything like the same extent.

Bombay.

In Bombay sunn-hemp, or *tag,* as it is called locally, is sown at the beginning of the monsoon in some parts of the Nasik and

D 2

Surat districts, and ploughed in when about four feet high, at the beginning of August.

The Agricultural Department has for some years been experimenting,[1] on the Alibag farm in the Konkan, and an increase of some 8 maunds of paddy per acre has been obtained by sowing *san* or *dhaincha*,—on land cultivated immediately after the removal of the previous crop,—and ploughing in the green manure at the time of flowering.

An increase of 7 maunds per acre was obtained by sowing these crops under irrigation in April and May, and transferring the green manure to double the area for ploughing in. Sowing in the previous paddy crop, before harvest, and sowing at the beginning of the monsoon, were both unsuccessful.

In addition to these results Mr. Gonehalli reports[2] that "At the Ratnagiri Farm the outturn of 'Kuryat' (high-lying) rice land green-manured with *san* sown in the beginning of the monsoon and ploughed down before sowing 'rahu' or sprouted rice seed, was increased by 477 lb. of grain and 933 lb. of straw per acre valued at Rs. 23-1-9. The cost of green-manuring was Rs. 6-13-8 per acre."[3]

The effectiveness of green-manuring with *san* has been demonstrated also at Ahmedabad and near Poona, as well as in Kanara. The Bombay Department is, in fact, in the words of the Director's Report for 1913-14, " actively preaching the practice of green-manuring " and about 10,000 lb. was distributed in the Konkan, and 400 lb. in Kanara in the year 1913.

Central Provinces.

Coming further north, in the Central Provinces, sunn-hemp and *sawri* (the local wild sesbania) have been tried at Raipur on poor 'dorsa'[4] soil, with good results in the case of *san*, and the practice is one of the items in the Department's programme of demonstrations in Chhattisgarh. Seed is sown at the beginning of the monsoon at the rate of 60lb. per acre and ploughed in at the end of July or beginning of August.

At Telinkheri, *Melilotus alba* sown in the standing crop and allowed to flower in the cold weather has also been found beneficial.

[1] *Annual Reports of the Department of Agriculture, Bombay Presidency*, 1911-1914.

[2] *Annual Report of the Department of Agriculture, Bombay Presidency*, 1913-14, page 57.

[3] All these figures should perhaps be regarded merely as an indication of possibilities, and here again the compiler would suggest that the value of a fodder crop grown under the same conditions would be a better guide to the real cost than the mere out-of-pocket expenses particularly in the case of crops grown under irrigation.

[4] Medium rice land.

Allan [1] in a recent paper has given figures which show a remarkable influence of bonemeal on the effect of green-manuring for rice, the plots to which bonemeal had been applied giving very much more greatly increased yields as a result of green-manuring than other plots.

North-West India.

In the North-west of India where canal irrigation introduces greater elasticity into the rotations, green-manuring for paddy has not been practised so far as the compiler can ascertain, though the practice of ploughing down the weeds and much of the standing crop of broadcasted paddy by way of thinning and manuring the remainder is referred to by Roberts, [2] in a note printed in 1909, as common in Kangra and in some parts of Kashmir.

Bihar and Orissa.

Further east, good results have been obtained at Dumraon in South Bihar as regards the yield both of paddy and of the succeeding crop of gram sown in the standing paddy before harvest, and at Cuttack, in Orissa, *dhaincha* has been found successful as a green manure, but the practice does not seem to have spread in either neighbourhood. Probably the time that elapses between the first opportunity of sowing the green manure and the transplanting of the paddy is too short in ordinary seasons for reliable results to be secured without the safeguard of irrigation such as is available on both the experimental farms referred to. Moreover, where irrigation is available, it can perhaps be used for more profitable crops.

Bengal and Assam.

In the great rice and jute growing area of Bengal it may seem surprising that the practice of green-manuring has not spread widely—more particularly as this is the home of *dhaincha* which has proved so useful for the purpose elsewhere.

Green-manuring has in fact been shown for many years back to be effective on the Department's farms, particularly at Burdwan, and a certain amount of *dhaincha* seed is annually distributed by the Department. The fact that the practice does not spread is perhaps partly due to the competition of jute, which no doubt pays better as a money crop than *dhaincha* as a green manure where the conditions are suitable for sufficiently early sowing and subsequent rapid growth. A closer study of the economics of jute and paddy cultivation than has hitherto been

[1] Green-manuring in the Central Provinces, *Agri. Jour., India*, Vol. X, Pt. IV.

[2] *Note on Manures in the Punjab* (Government Press, Lahore), 1913.

possible in Bengal would be a necessary preliminary to any serious attempt to increase yields by reducing the area of directly profitable crops.

The subject of green-manuring is discussed in a note prepared by Meggitt and Birt for the Meeting of the Board of Agriculture in 1911 in which the growth of green manures with the aid of small dressings of lime and phosphate is advocated as a promising line for scientific and economic investigations; and the best available information as to experimental results in Bengal is probably that given by Meggitt in a *Note on Manures* published in 1912 as Bulletin No. 23 of the Assam Department of Agriculture.

After comparing the use of *dhaincha*, sunn-hemp, and cow-peas for manuring in general, Meggitt gives the following accounts of experiments carried out at Dacca :—

"*Dhaincha* and sunn-hemp were sown in April and ploughed in about the middle of July. The ***san*** was a failure in 1908 and not very promising in 1909.

"The *dhaincha* in both years was about 1 foot high or rather more when ploughed in. The crop suffered somewhat from water-logging at an early stage. The plots green-manured with *dhaincha* came out remarkably well, however. If by a little earlier sowing a bigger crop of *dhaincha* could be obtained, there is every indication that green-manuring will be the cheapest manure for winter paddy on this land. The profit, per acre, obtained after *dhaincha* was greater than that from all other plots, excepting the bone-meal plot which showed an equal profit, but at a greater expenditure. We are so far convinced of the value of this form of green-manuring for winter paddy that this year we are carrying out several demonstrations in the Dacca district with *dhaincha* for winter paddy. On account of the check which the *dhaincha* usually receives at an early stage by reason of the water which accumulates on the low-lying paddy land, it would seem probable that some other kind of green manure crop will have to be sought for—one which is better able to withstand the conditions named above."

At Rajshahi, "Cowpeas ploughed in was used as a preparation for winter rice. The average yield per acre of two duplicate series of experiments was as follows:—

	Green Manure with Cowpeas			No manure		
	Mds.	Srs.	Ch.	Mds.	Srs.	Ch.
Paddy	19	28	0	16	30	0
Straw	23	23	0	25	30	0

"Although the cowpea crop did not grow very well on this farm, its use as green manure resulted in an appreciable increase in the yield of grain, though curiously enough it was accompanied by a decrease in the straw. The net profit from green-manuring amounted to about Rs. 5 per acre."

In the note [1] referred to above Meggitt and Birt mention the practice common in many parts of India of sowing *Lathyrus sativus* in the standing paddy before harvest as a fodder for cattle. *Lathyrus sativus* is of course not the only crop thus sown. Gram and linseed are common crops grown in this way in South Bihar and no doubt other crops are used in other parts of India. The practice can hardly be called green-manuring except in the case of typical green manure crops like *san* and *dhaincha*, but there is no doubt that when even a leguminous fodder or seed crop is introduced into the rotation in this way, it adds something to the fertility of the soil.

In Assam the green-manuring of paddy has not been developed.

Burma.

With regard to Lower Burma Mr. McKerral, Deputy Director of Agriculture of the Southern Circle, writes, from Insein :—

" In the case of the flat plains of Lower Burma which receive a rainfall varying from 90 to 200 inches and over, and which, with the exception of small areas of sugarcane in the Yame-thin and Thaton Districts, are cropped entirely with rain-fed paddy, green-manuring, as shown by trials at the Hmawbi Station, has hitherto not been successfully accomplished. This is due to two circumstances; firstly that the soil of these rice fields is so hard that cultivation is impossible until the rains break, and secondly that the rainfall comes so abruptly that crops sown are swamped and destroyed. Trials have been made by sowing after the reaping of paddy but the soils retain so little moisture that most of the crops tried (*Crotalaria*, *Sesbania*, Indigo, etc.) grew to about 6 inches height and then flowered and withered. It still remains to be seen whether ploughing after the paddy harvest so as to get a good tilth, allowing the land to be in bare fallow, and sowing the green manure seeds just before the rains break, might not be a success. This is being tried at Hmawbi during the present year. In connection with these rice lands there is one fact to be borne in mind. During the period which elapses between the break of the monsoon, in May, and the middle of July when the fields are first ploughed, a very great growth of grass, sedge,

[1] *Bulletin* No. 23 *of the Department of Agriculture, Assam,* 1912.

and above all paddy from last year's shed seed, takes place, and if one of the main functions of green-manuring be incorporation in the soil of a large bulk of organic matter, that function must be performed to some degree by the above-mentioned growth, for much of this growth is invariably trampled down and ploughed into the soil. Hence the need for special green manure crops may not be so imperative as in regions where such a growth does not take place."

There seems to be little doubt that green-manuring would be possible in the canal-irrigated rice tracts of the Shwebo, Mandalay and Mon canals, should it ever become necessary for the maintenance of fertility.

3. Tobacco and Valuable Cold Weather Crops.

Green-manuring for tobacco and for valuable cold weather crops on unirrigated land differs from that practice in connection with paddy chiefly in the fact that the green manure cannot be puddled in and therefore requires a longer time to rot : on the other hand there is a longer time available before the land is required.

Tobacco in North-East India is perhaps the most suitable of all dry land crops for growing on green manure.

The cultivation of tobacco has been very thoroughly investigated by Howard at Pusa and the system of green-manuring with sunn-hemp has been worked out and the results published by him in several papers,[1] an illustration from one of which is given opposite. Leaving the scientific aspects to be discussed later, the practical conclusions, as summarized in one of the publications cited are as follows :—

"The experiments with *sanai* as a green manure for tobacco in the Botanical Area at Pusa have led to very definite conclusions. Drainage is essential for success with green-manure on the high lands. The *sanai* should be sown on the early rains in May and ploughed in as near July 15th as possible. Where large areas have to be dealt with, the period from July 7th to July 21st would be suitable. Any crop left on July 21st should be cut at once, left on the surface and ploughed in as soon

[1] Howard and Howard, *Agricultural Journal of India,* Vol. VII, Pt. I, page 79, 1912, and Vol. IX, Pt. II, page 201, 1914.

Studies in Indian Fibre Plants, No. 1, *Mem., Dept. of Agri., India, Bot. Ser.,* Vol. III, No. 3, page 188.

Some Aspects of the Agricultural Development of Bihar, *Bulletin No. 33 of the Agricultural Research Institute, Pusa,* page 5.

The Improvement of Tobacco Cultivation in Bihar, *Bulletin No. 50 of the Agricultural Research Institute, Pusa,* page 10.

EXPLANATION OF PLATE VI.

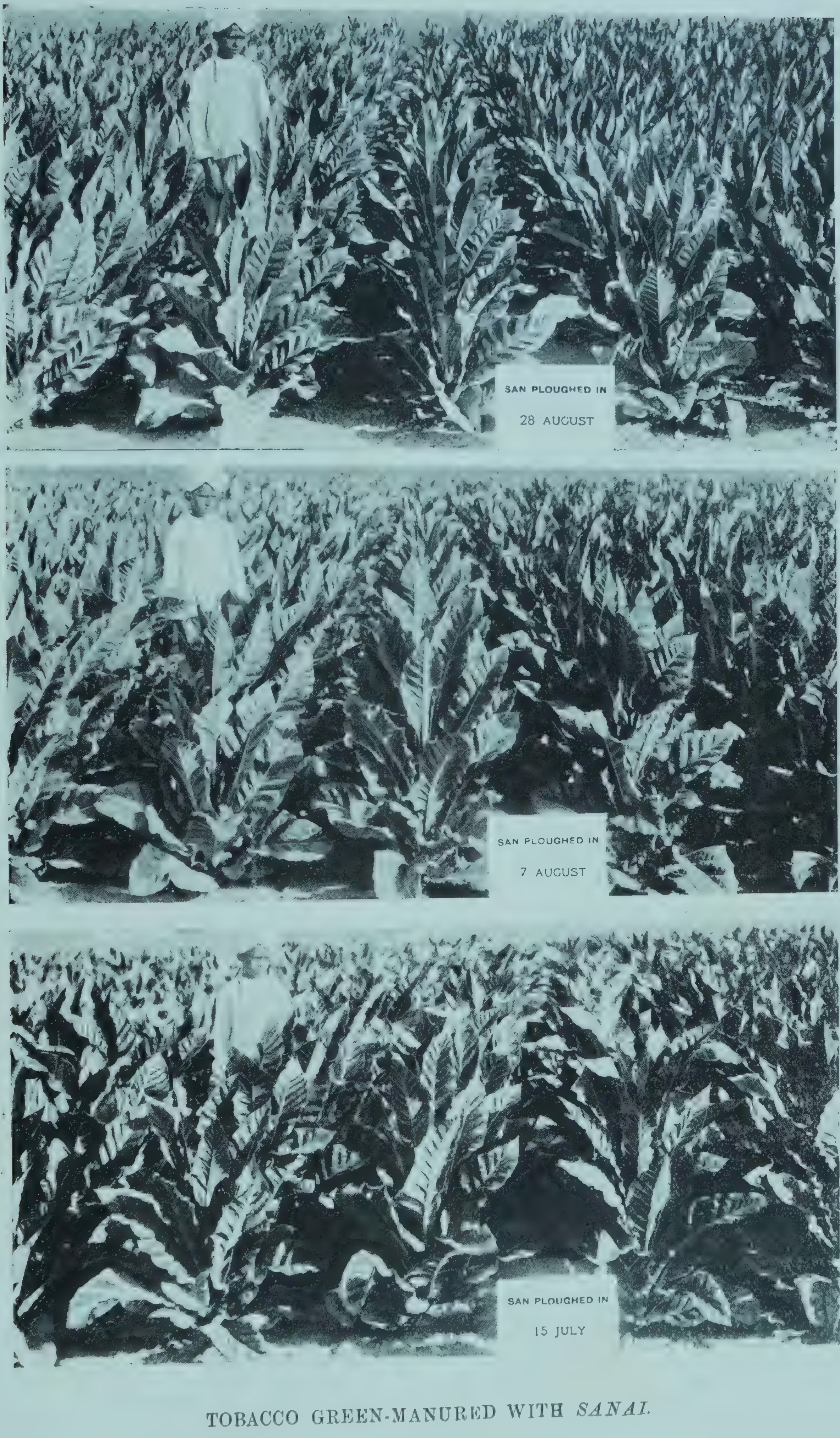
An even plot of light, high-lying, drained land in poor condition was green-manured with *sanai* for tobacco and divided into three plots. In the first plot the *sanai* was ploughed in on July 15th, in the second on August 7th and in the third on August 28th. Cigarette tobacco (Type 28) was planted into all these plots on September 25th and 26th, the plants being set out 30 inches apart each way. The dates of sowing and ploughing in the *sanai* were as follows :—

	Sanai sown.	*Ploughed in.*
Plot 1	May 18th	July 15th
Plot 2	June 15th	August 7th
Plot 3	June 30th	August 28th

Sown in this way the amount of green manure ploughed in all the plots was practically the same.

The results of the experiment were very striking. The tobacco in plot 1 grew very rapidly from the beginning and has given the maximum crop that can be grown for cigarettes. Plot 2 is not so good while plot 3 is poor. The results are shown in the Plate. In all the three cases the photographs were taken at the same distance from the camera.

PLATE VI.



TOBACCO GREEN-MANURED WITH *SANAI.*

as possible. To get the maximum benefit of the green crop the interval between the ploughing in of the *sanai* and the transplanting of the tobacco should be eight weeks. A longer or a shorter time leads to loss."

At Pusa and at Sripur, in the Saran District, green-manuring with sunn-hemp in combination with superphosphate is the routine method of maintaining fertility, but the conditions cannot be said to be strictly economic. The method adopted at Sripur is described as follows by Mackenzie [1] in the Farm Report for 1912-13:—

"Sunn-hemp or Cowpea—but mainly the former—are sown broadcast at the rate of 45 seers per acre at the first inset of the monsoon, or a little earlier should there be a good shower of rain at the end of May, and the crop is ploughed into the land by Howard's D. Plough about the first week in August, by which time the sunn-hemp has acquired a height of from four to five feet. It is then left to rot for about one month, when it is cross-ploughed with the same plough, and after a few days, levelled off with the harrow or country plough; superphosphate—40 per cent. water soluble phosphoric acid—is sprinkled over the open furrow at the rate of one maund per acre (combined with about two maunds per acre of dry soil for facility of sprinkling), laddered, and mixed in the soil at once with country plough or harrow. This is the procedure I have adopted during the year under report, and will adopt again during the current year. It is then left until the time arrives to open the land for the reception of the seed, as soon after the finish of the *hathia* as possible."

At Pusa plots of 100 square feet of sunn-hemp were cut and weighed in 1914 and it was found by Leather that a fair crop, ready to plough in yielded some 3,000 lb. per acre, and a good crop 4,200 lb. of dry matter, containing about 50 and 70 lb. of nitrogen respectively.

Field and Laboratory experiments were started at Pusa by Hutchinson and Milligan in 1912—designed to elucidate both the practical and scientific aspects of the subject, and to extend over at least three seasons. An account of the experiments in 1912-13 was published as *Pusa Bulletin* No. 40, in 1914, but the conditions were abnormal and no certain conclusions could be drawn from the field experiments. The scientific aspect will be dealt with later (pp. 50-53).

In Meggitt's note,[2] cited above, the following account is given of the use of *dhaincha*, sunn-hemp and cow-peas for high land crops on the Dacca Farm:—

"*Dhaincha* (*Sesbania aculeata*).—Is particularly useful as green manure in this province, as it grows well on almost every kind of land. It

[1] *Report on the Agricultural Stations in Bihar and Orissa*, 1912-13, page 64.

[2] *Bulletin No. 23 of the Department of Agriculture, Assam*, 1912, page 3.

makes good growth even if the lower parts of the plants are submerged in water, though it cannot stand too much water in a very young stage. It produces a large amount of leaves and will grow up to 10 to 12 feet high. The stems, however, become very woody if left too long and are not easy to incorporate with the soil afterwards. If allowed to stand too long and become woody, the stems do not easily decompose in the soil; in fact they more often persist throughout the ensuing cold season, opening up the soil to such an extent as to diminish the water content of the surface soil at a time when moisture is extremely valuable. Perhaps the most suitable stage to plough it into the soil is when it is 5 or 6 feet high, but no rule can be laid down, as other considerations, such as the crop which is to follow, and the character of the season, largely determine when ploughing in shall be done. *Dhaincha* should be sown as early as possible after the first seasonable rains fall, and should be ploughed in by about the middle of July. On the Dacca Farm, *dhaincha* sown early in May grew luxuriantly, producing a 5 to 6 feet crop which was ploughed in early in July with excellent results, decomposing entirely in a short time.

"On the old alluvial soils of the Dacca district (and the same would no doubt apply to similar soil formations in other parts of the Province), some preliminary work done by me last year shows that a good crop of *dhaincha* adds much more organic matter and nitrogen to the soil than we can get from sunn-hemp.

"*Sunn-hemp* (*Crotalaria juncea*).—This crop, though producing a fair amount of vegetable matter, does not do so well in the deltas of Eastern Bengal as *dhaincha*. It would probably do better on the lighter types of land, where water-logging is not so likely to occur. It cannot compete with *dhaincha* on stiff land and in districts of heavy rainfall. It is also, with us, much more liable to attacks by insect pests than *dhaincha*.

"*Cowpea* (*Vigna catiang*).—Grows very luxuriantly on light loamy soils, producing a large dense mass of vegetation, not in the least woody, which decays most readily in the soil. Not a vestige of it can be found after about a month after incorporation with the soil. The difficulty we have found with this crop is in getting it into the land. It cannot well be ploughed in as the long stems drag into an enormous mass in front of the plough. It has to be put in with the *kodali*.

"By cutting it and allowing it to partially wither and dry for a day or two, if weather permit, it can be more readily got into the soil. Mr. Bose informed me that he adopted this method at Rangpur with excellent results. In America cowpeas are largely used as green manure, and experience there goes to show that the vines can be very successfully buried

by the Rotary Disc plough. The latter, however, is probably of rather heavy draught for the average Indian cattle.

"*Experience of green-manuring at Dacca.*—A high land improvement experiment in green-manuring was commenced in 1908 and is intended to be permanent. Briefly it consists of four plots, each 2-3 acres in area. Two of the plots are being cropped with *aus* or jute in the *kharif* season followed by a leguminous crop (*mung* or *mati kalai*) in the *rabi*. The other two plots are being green-manured every rains, the one with *dhaincha*, the other with sunn-hemp, followed by a non-leguminous crop in the cold weather.

"We have to admit that up to the present the green manure plots have not shown that measure of improvement which was expected and hoped for, although they now produce a small crop of oats in the cold weather, whereas this crop would not grow at all before. We are so convinced that this lack of greater response to green manures is due to a thoroughly unhealthy condition of the soil by virtue of its extreme poverty in lime, that we are this year cross-dressing with lime."

In the Dacca Farm Report for 1911-12 there is a further most interesting account by the same author of more recent results, which brought out the great effect of lime on the *dhaincha*, as well as the mutually beneficent action of the green-manure and bone meal [1] on the succeeding crop, on this acid soil. The effect of *dhaincha* without phosphates on the immediately following cold weather crop was however a negative one, and this is attributed to the woody nature of the *dhaincha* stalks, which did not rot, and probably adversely affected the moisture-retaining capacity of the soil for the time being.

In Bombay sunn-hemp or *tag* is in some districts used as a green manure for tobacco and other winter crops. In leaflet No. 2 of 1911 of the Bombay Department it is stated that—

"When *tag* is ploughed in as preparation for a winter crop it is .... turned under when it just begins to flower. Some put the plough in the standing crop. Some beat the crops with sticks before ploughing; others let their cattle in and then plough, while some use a plank leveller and then plough the crop. Some pull or cut the crop and put it in the furrow opened by the plough."

Patil in a bulletin, previously referred to, makes the following recommendation on the subject:

"In the case of dry crops like tobacco and *rabi-jowari* grown in retentive black soil, it is necessary that the ground should be fairly dry before the *tag* is ploughed in, otherwise the soil gets puddled. On the

[1] *Cf.* Allan (*loc. cit.* p. 35).

other hand, it is essential that the *tag* when ploughed, should be properly buried and that rain should subsequently fall; otherwise it will not rot properly, nor will the ground become sufficiently compact. When conditions are favourable, the *tag* soon rots, and the field is ready for the new crop in about a fortnight. It will be realized that the time for turning in the crop has to be chosen with care and discrimination, with reference to the state of the soil and the prospect of subsequent rain. *Tag* sown as green manure for tobacco, is, in the Satara District, generally turned in during August, and the tobacco seedlings are planted early in September. If sown as manure for *rabi-jowari* it is usually turned in in September, and the *jowari* sown in October. Where there is fear of the late rain failing, it would be wise to turn it in earlier."

In the Central Provinces, experiments have been tried at Raipur, Nagpur, and Hoshangabad, and the results have been collated by Allan, with a view to the present compilation, in a paper printed in the *Agricultural Journal of India*, Vol. X, Part IV, October 1915.

The experiments at Nagpur have shown an intimate relation between the amount of rain falling in the interval between the ploughing in of the green manure and the sowing of the following wheat crop, and the yield of the wheat crop; this is very clearly illustrated by graphs in the paper referred to—one of which is reproduced opposite.

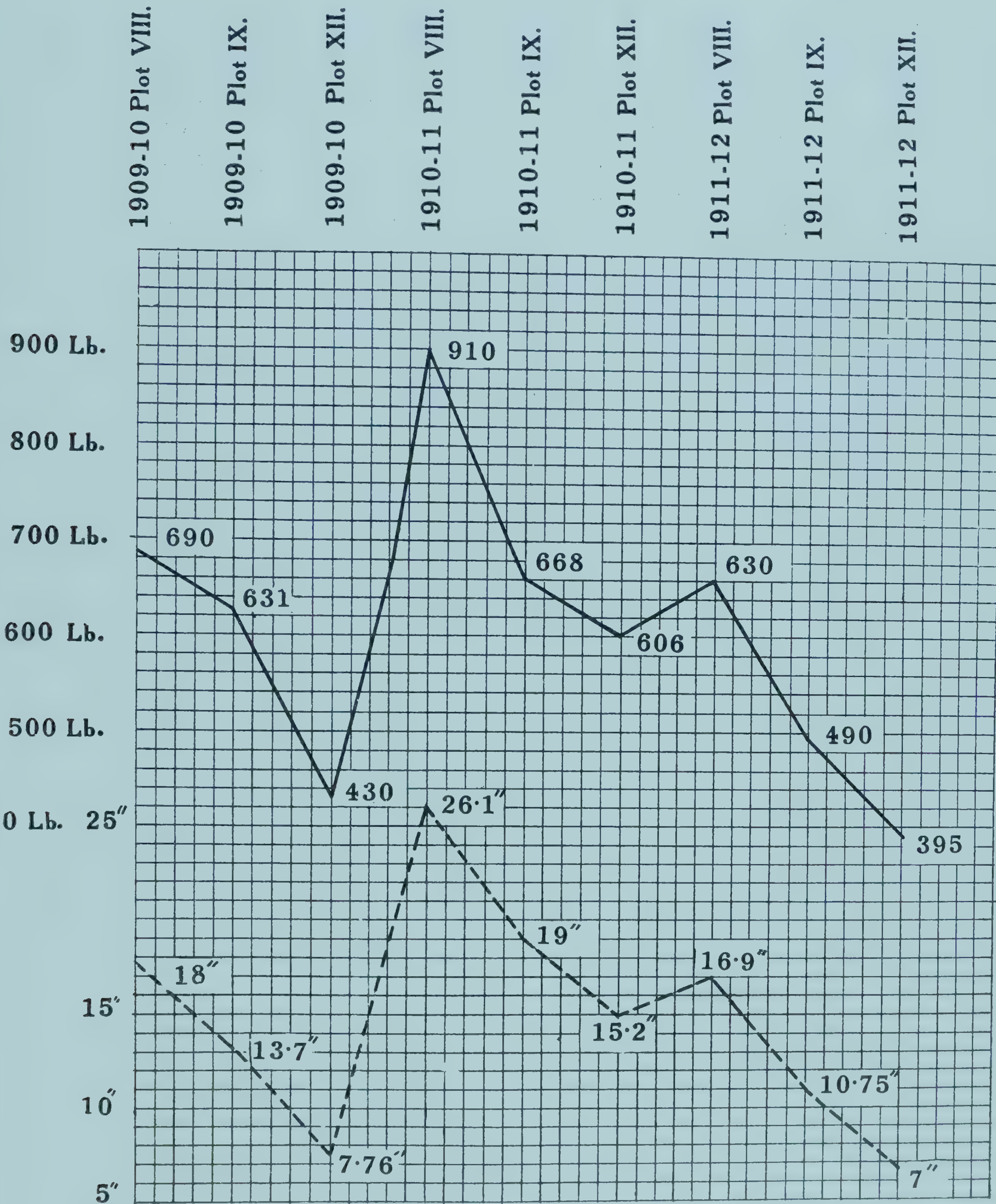
At Hoshangabad on the other hand no such relation appears to exist, and Allan endorses the view expressed by Evans that the effect of green-manuring on the heavy soils of the Nerbudda Valley is masked by the fact that it is frequently necessary to plough the manure in when the soil is too wet.

From other Provinces little information is available as regards the green manuring of this class of crops, beyond that referred to below, in connection with irrigation. We may therefore go on to consider the case of jute, sugarcane and garden crops, the value of which gives them a special position with regard to manuring.

4. Jute, Sugarcane and Garden Crops.

The position of jute is of course quite peculiar, owing to the climatic and physical conditions of North-East India. The growth of a crop for green manure is out of the question on typical jute land, during the monsoon, but an interesting practice is thus referred to in Meggitt's note already cited:—"In parts of the Rangpur, Pabna and Mymensingh districts, sunn-hemp is grown and ploughed in as green manure for the jute crop, though in many cases the stems and tops are removed for various purposes, and only the roots are left in the ground."

Graph showing the relation of the wheat yield after green-manuring to the amount of rain received between ploughing in the green crop at different dates and the sowing of wheat.



Wheat yield in lb. per acre———
Inches of rain received after inversion of the green crop and before sowing- - - - - - - - - -
Plot VIII ploughed in on 27-7-09, 20-7-10, 20-7-11.
Plot IX ,, ,, 10-8-09, 13-8-10, 12-8-11.
Plot XII ,, ,, 24-8-09, 27-8-10, 26-8-11.

The compiler's attention was drawn to this practice by Mr. Finlow, Fibre Expert to the Bengal Government, through whose kindness he was enabled to investigate this practice personally, in the Mymensingh District. The land is cultivated with care for the sunn-hemp, which is sown in October, and produces a good crop that comes into flower at the height of about four feet at Christmas time. This is fed off systematically by cattle, which are usually tied to stakes, and eat the flowers and leafy part of the stem greedily, trampling down the remainder. This is then ploughed in, and results—according to the cultivators on the spot—in some 50 per cent. increase of fibre in the succeeding jute crop. The price of sunn-hemp seed is, however, about Rs. 10 per maund, in this district, and the cultivators said that if the price of jute remained low the practice would not pay. Babu Bhavatosh Datta, Agricultural Inspector of the Pabna Division, referring to the Serajganj sub-division where the practice is said to have originated, writes that "on account of the lull in jute business and partial failure of the rice crop this year, the cultivators in many parts have put down food crops on jute lands in place of sunn-hemp." The primary object of the practice is therefore the production of a heavy crop of high-priced jute, though the value of a leguminous fodder crop, in a district notorious for the poor feeding of its cattle, must be considerable at this time of year. The poverty of the rape crops growing alongside those of sunn-hemp at Gafargaon (Mymensingh District) gave the impression that the latter was a more suitable crop for the conditions—the essential peculiarity of which is no doubt the exhaustion of nitrogen by the jute. In the peculiar circumstances of the jute districts, where the value of the monsoon crop is out of all proportion greater than of that grown in the cold weather, the practice described would seem to rest on a sure foundation.

Possibly a similar system might be pursued with sugarcane where sufficient moisture for the green manure and for sprouting the cane can be ensured by irrigation or otherwise.

Wherever sugarcane or garden crops are grown the problem of manure is a serious one and green-manuring is being increasingly resorted to to supplement other manure.

In Madras Wood [1] says: "For certain crops which, though grown on wet lands, are yet not grown under swamp conditions, the use of green leaves is already known. The most common is the practice of applying wild indigo (*Tephrosia purpurea*: *Vempali, Kolinji*) to sugarcane, which is adopted both in the Northern and Southern Parts of the Presidency and is found in districts so far apart as Vizagapatam and Coimbatore.

[1] *Madras Agricultural Calendar*, 1912-13, p. 10.

A heavy price is paid at times for the leaves; as much as 6 to 10 cartloads being applied per acre, each cartload costing about Rs. 6.

The leaves are put on when the trenches are dug, the plants being laid alongside the stems of the canes and covered with the earth removed from the trenches. In parts of the Godavari district, sunn-hemp (Tamil *shanal*; Telugu *janumu*) is frequently sown when canes are planted, and when 2 or 3 feet high is buried beside the canes when the trenches are dug. In betel gardens again, it is the practice to bury alongside the young betel plants, the leaves trimmed from the Sesbania (Tamil *Agathi*; Telugu *Avisi*) plants, which are to serve as standards for the vines. A very considerable quantity of green stuff may thus be added to the soil and under the influence of the moisture which the betel plant requires rapidly decomposes. Even on lands which are in no sense wet lands, leaves may be used in districts where the rainfall is sufficiently heavy to permit of the leaves rotting well. On the West Coast, in the districts South Kanara and Malabar, with the heavy rainfall brought by the south-west monsoon, the use of leaves is well known. Certain leaves moreover are recognized as possessing special qualities which fit them for special crops, and the use of nux-vomica (Tamil *Yetti*; Telugu *Musini*) and *Phyllanthus Emblica* (Tamil *Nelli*; Telugu *Usiri*) leaves, for ginger (Tamil *Inji*; Telugu *Allam*), is universal.

"It is clear then that we have many instances of the adoption of the practice of green-manuring (applying green leaves) to garden lands and the value placed upon them. In the cases noted however, with the exception of the use of *Agathi* leaves in betel gardens and sunn-hemp for sugarcane, the leaves have been procured from outside and brought to the lands, the expense being high, but being counterbalanced by the value of the crop. For any wide extension of the practice, this expense will have to be avoided, and this can be done by growing the crop on the land itself and ploughing it in before the main crop is sown or transplanted. This it may be remarked is the practice already adopted by the cane cultivators of Hospet, who invariably take a crop of sunn-hemp before cane and plough it under as green manure."

As regards Bombay, Main in a note on manures contributed to the discussion of the subject at the Board of Agriculture's Meeting in 1911 wrote: "Green-manuring, more particularly with sunn-hemp is largely adopted in Bombay in garden lands and on sugarcane areas. Whenever the supply of bulky manures for sugarcane is deficient a crop of *san* is taken and ploughed into the land in preparation for the cane crop.

"In the Southern parts of the Presidency *Niger* (*Guizotia Abyssinica*) is also a favourite crop."

Patil [1] gives the following information as to the use of sunn-hemp for manuring these crops:—"Its most important use as a green manure is perhaps for sugarcane. For this purpose it is sown in June, 40 or 50 lb. to the acre. When it is about 5 feet in height and just about to flower, it is cut close to the ground and the land is ploughed. The *tag* is laid in the furrow behind the plough and buried by the earth turned over by subsequent furrows. Since the season for planting sugarcane will not then have arrived, in some cases *tag* seed is again broadcasted on the same land, and the crop is subsequently turned in. In the case of sugarcane the use of the land for *tag* prevents any other crop being grown, but a saving of from 25 to 40 cartloads of manure is effected, and good results are obtained.

"In Nasik District *tag* is extensively used as a green manure for rice, onions, garlic and to some extent for sugarcane and wheat. Rice in the Sinnar and Dindori Talukas, onion in Niphad Taluka, and garlic near Sinnar are regularly manured in this way.

"In the Surat District a modification of green-manuring with *tag* is practised. About 20 lb. per acre of *tag* seed is broadcasted in the *suran* (*Amorphophallus campanulatus*) beds when the *surans* are planted in May. In six weeks' time when the *tag* is about three feet high, it is pulled up and broken into pieces and left lying in the *suran* fields to serve as manure."

There is no considerable amount of information available concerning green-manuring for this class of crops in the Central Provinces, Bengal, or Burma, nor does it seem to be practised to any considerable extent in the United Provinces; but it is probable that with the extension of sugar factories in the East of those Provinces, as in Bihar, green-manuring with sunn-hemp will be found a useful means of maintaining fertility where manures are deficient. In these Provinces the *san* has to be grown in the previous monsoon, but the value of the cane crop may easily compensate for the sacrifice.

It is stated in the report of the Assam Department of Agriculture for 1912 that green-manuring once in a four years rotation is the routine practice on the Jorhat Farm, and has proved very successful. The practice has been continued, and in the 1913-14 Report it is stated that *dhaincha* and sunn-hemp have been used on a large scale, and several varieties of Madras and American cow-peas are being tried. At Upper Shillong local *mati kalai* has proved inferior to soy-beans.

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[1] *Bulletin* No. 47 of 1911, *Department of Agriculture, Bombay.*

In the North-West Frontier Province, *shaftal* (*Trifolium* sp.) occupies such an important place in the rotation as to make green-manuring almost unnecessary : an article by Robertson Brown, published in the *Agricultural Journal of India* for January 1912, gives an account of the cultivation of sugarcane in connection with this important forage crop.

In the Punjab, Roberts stated in the note above referred to that green-manuring is fairly common in some districts such as Jullundur; he says :—

"The crops generally used for this purpose are sunn-hemp (*Crotalaria juncea*) and *guara* (*Cyamopsis psoraloides*). As a rule, green-manuring is applied to grade up poor sandy soils, and in medium soils as a preparation for sugarcane. Both the above plants are legumes, and thus enrich the soil in nitrogen obtained from the air. Sunn-hemp is preferable to *guara*, as its bulk is generally greater in comparison, thus introducing more organic matter into the soil. Where the rainfall is small, green-manuring is open to the objection that the available moisture having been used in this way, there is none left for the succeeding crop, nor is it possible for the green manure to decay properly in the soil, on account of the lack of moisture."

5. Irrigated Crops.

This brings us to the last group of crops in our classification, *viz.*, ordinary crops grown on irrigated land.

The essential difference made by facilities for irrigation is that while a green manure crop can sometimes be grown without, or with a minimum of, irrigation, there is no fear, where such facilities exist, of absolute deficiency of moisture for the primary crop or to rot the manure, or of an excess of rain interfering with the subsequent cultivation; the value of the succeeding crop should not therefore have to pay for the risk of partial failure.

At Lyallpur in the Punjab, there seems to be no doubt but that the practice is a good one on light soils, and the following leaflet was issued in 1913 by the Department of Agriculture :—

"The Canal Department have agreed, for a period of 5 years, to levy no water rates on *san* or indigo crops grown for green-manuring purposes with irrigation from the Lower Chenab and Lower Jhelum Canals. That is to say, if *san* or indigo is grown for the above purpose in the *kharif* season and followed by a *rabi* crop (on the same land), only the water rate for the *rabi* crop will be charged.

"The conditions are :—

(1) That the green-manuring crop must be ploughed into the land before September 15th, otherwise water rates will be charged.

(2) That none of the crop be removed from the land.

"The growing of green-manuring crops in the *kharif* season is a cheap method of increasing the fertility of the soil and so obtaining a heavy wheat crop in the *rabi* season. *San* is particularly suitable for this purpose as it not only is a quick growing bulky crop but also belongs to the same class of plants as *mung, mash, senji,* etc., which, as *zamindars* know, tend to enrich rather than impoverish the land.

"There is no need to detail the cultivation. The following points ought to be observed :—

(*a*) The crop should be grown *barani* as far as possible, irrigation given only when absolutely necessary.

(*b*) The seed should be sown in July after rain if possible.

(*c*) The crop should be ploughed in by the first week of September. There is often rain at this time, which should be taken advantage of.

(*d*) In ploughing in, the crop should be first levelled with the *sohaga,* or where the owner has a reaper, it may be cut. The crop should then be ploughed in. To obtain the full advantage of the green manure it should be covered over with the earth. For this purpose an English, furrow-turning plough ought to be used. After ploughing, wheat may be sown in the end of October on the land. The best results will be obtained on poor land. On such lands an increase of 25 per cent. to 50 per cent. on the succeeding wheat crop may be looked for."

An interesting article, previously referred to, was also published by Roberts, in 1913 in the *Agricultural Journal of India,* Vol. VIII, Part IV, dealing shortly and lucidly with the economic side of the question—perhaps the only paper published in India that has dealt with this aspect satisfactorily.

At Cawnpore no such clear advantage has been found to attach to green-manuring. In 1911 the results of the experiments, which had then been in progress for 17 years, were summed up as follows in the Report of the Cawnpore Agricultural Station :— "A reference to the 1909 report will show that the green-manuring plots have had a leguminous

crop ploughed in and have been cropped with wheat every year since 1893-94 with no apparent result. In 1907-08 two plots were limed to see whether the low production was due to sourness caused by over-manuring. In that year, which was an exceptionally good one for wheat throughout the farm, fair outturns were obtained, but the limed plots showed no advantage over the unlimed plots.

"In 1908-09 all the plots were cropped unmanured, gave poor outturns, and showed little difference.

"In 1909-10 *urd* was sown as early as possible, and ploughed in early in September. It obviously did not rot properly, and no difference between the plots, which all yielded badly, was obtained.

"In 1910-11 Sunn-hemp was sown with irrigation in May, and ploughed in early in the rains, it apparently rotted well, but all plots again yielded badly. It has been decided therefore to restart the experiment on a new series of plots which have been tested for equality for 3 years.

"An attempt will also be made to ascertain the reason why the old plots are now in such bad condition."

Little has been ascertained by subsequent experiments except to show that the permanent plot benefited very much by the addition of superphosphate. A new series of plots previously tested for uniformity was green-manured in 1911, and three crops of wheat have since been taken off it without further manuring, but the results are again contradictory. In 1913-14 an experiment with sodium nitrate on the old plots gave equally contradictory results, and after 20 years of continuous wheat cropping it has now been decided to place the field under a rotation. There is no doubt but that, as stated in the 1913 report, "the results of ploughing in green crops" on the Cawnpore Farm "are erratic, and apparently there are factors that are not understood at present."

PART III.

SCIENTIFIC WORK.

Work at Pusa and at some Provincial Centres.

This brings us to the question of the necessity for more scientific work. With the rapid development of district work by the Agricultural Department, much of the experimental work in the field can hardly be said to have been scientifically conducted. In most cases the supervision of cultivation and harvesting must have been left to very imperfectly trained subordinates. The scientific aspect of the subject has therefore been, so far, kept in the background, and general results only have been quoted.

And, as much of the scientific work has only recently been put in hand and is still *sub judice*, it is proposed now to give only a short sketch of what is going on at Pusa and in some of the Provinces.

Pusa.

Howard's work at Pusa has been referred to above (p. 38). The conclusions quoted there may be said to be based on work that is truly scientific, in that it has been strictly supervised by accredited observers; and the observations recorded are therefore properly qualified and reliable, even when they do not admit of exact expression in the form of measurements or weighments, as for instance in the case of the 'ripening off' of tobacco; or where the evidence recorded is chiefly visual, as in the illustration facing p. 38 above.

Further investigations suggested by the earlier observations are:—

(*i*) A survey of the varieties of sunn-hemp in India with particular reference to their rapidity of growth and capacity for seed production.

(*ii*) The study of methods of treatment of land, particularly heavy soils, so as to avoid, or mitigate the effects of, water-logging a condition which has been observed to result in a loss instead of a gain from green-manuring for dry land crops.

(*iii*) Laboratory investigations into the cause of this injury, with particular reference to the question of oxidation in soils.

(*iv*) Laboratory investigation into the reasons for the observed effect of an excessive interval between ploughing in the manure and planting the tobacco; and field experiments with crops other than tobacco.

(v) Experiments as to whether under certain circumstances the manure crop can with advantage be cut and left to wilt before ploughing in.

In concluding his article in the *Agricultural Journal of India* for January 1912, Howard wrote:—

"Enough has been said to show that such an apparently simple operation as the ploughing in of a green manure crop involves many considerations, and also indicates the need both of careful field experiments accompanied by detailed and accurate records, as well as laboratory investigations from the chemical and biological standpoints. It is suggested that, where negative results have been obtained in the past, the real cause of the want of success may be found in the time-factor having been overlooked, or in subsequent water-logging of the land. In all such cases the work should be repeated. The importance of increasing the water-holding capacity and fertility of the soil is so great in India, and green-manuring is such an easy way of bringing this about, that no pains should be spared to find out experimentally the factors on which success depends. In addition to the field experiments it is also desirable that the matter should be investigated from the chemical and biological aspects."

The first, second and fifth of the above lines of investigation have since been carried on in the Botanical Area at Pusa, while further observations have suggested that, at Pusa, tobacco after sunn-hemp does not ripen off as sharply or evenly as that grown with *seeth* or farmyard manure, and that supplementary manure may be necessary—a point which is also under investigation.

Meanwhile Hutchinson has taken up the question of green-manuring from the bacteriological point of view, and, in the bulletin previously referred to (p. 39), details the principal points under observation as follows:—

"*Field*—

(1) Best stage of maturity for burying green crop.
(2) Best method of burying, with special reference to depth, and subsequent treatment of soil.
(3) Effect of addition of artificials, especially superphosphate, bonemeal or other manures, upon growth and decomposition of green manures.
(4) Effect of distribution of rainfall.

This last factor, although an uncontrollable one, is of prime interest and importance, as will be seen from the following report of the first season's experiments, and may be taken

to account to a large extent for the very varying opinions prevailing as to the utility of green-manuring as a part of field practice.

"*Laboratory*—

(5) Rate of decomposition of green crop in soil under conditions varied in accordance with the field experiments.

(6) Effect of varying moisture-content of soil correlated with (4).

(7) Fate of nitrogen content of green crop as determined by varying conditions; maturity, depth of burial, aeration, water content.

(8) Rate of formation of humus under varying conditions.

(9) Effect of artificials, etc., as in (3).

(10) Soil organisms concerned in various stages of decomposition of green crop; this branch of enquiry will of necessity involve a long period of observation; and may not be sufficiently complete to allow of publication of results together with those which will be obtained from the field and other laboratory experiments. During the season 1912-13 indications were obtained of the fact that the first stages of decay of the green crop are brought about mainly by fungi, bacteria not appearing to take any prominent part until somewhat later; this relation, however, will no doubt depend upon local soil conditions, and the elucidation of the point will require the co-operation of the Imperial Mycologist, which I hope to obtain. The variations observed in this laboratory in the relative power of different soils to deal with and decompose organic matter make it probable that it would be wrong to assume that all soils contain the necessary organisms for successfully decomposing a green manure, just as it is wrong to assume that all soils contain the necessary organisms for producing root nodules on leguminous plants. It is probable that such decomposing organisms are present in most arable soils, but it is also probable that it would be possible to discover methods of treatment of such soils which would insre the development of the optimum number of these organisms, and even to introduce new and more physiologically active species."

The work is still in progress, but a very definite confirmation has been obtained of Howard's observation as regards the 'time factor'

in that, however the moisture conditions or concentration of nitrogenous matter were varied, Hutchinson has found the maximum amount of nitrates after 8 weeks' incubation of sunn-hemp in Pusa soil, as compared with the amount found after longer or shorter periods. It is however suggested that it may be possible to extend this optimum period "by retarding the rate of decomposition of the green manure, as has been shown to occur as the result of deep burial of mature plant."

An interesting suggestion is made by Hutchinson in connection with the effect of different rates of transpiration of water by different green manure crops. He says :—

"In considering water supply as a limiting factor in the successful use of green manures, the point of view of the decomposition of the buried plant tissue in the soil is not the only or even possibly the most important one to be kept in mind. The loss of soil moisture by transpiration is very considerable and has been shown at Woburn by Voelcker to be the determining factor in causing the failure of vetches as a green manure as compared with mustard, the greater loss of water from the soil during the growth of the former more than counterbalancing the addition of nitrogen by the leguminous crop. Thus any shortness of rainfall after burying a green manure such as *Crotalaria juncea* would not only prejudice the growth of the succeeding *rabi* crop by preventing proper decomposition of the buried plants, but would do so as well by failing to make up for the soil moisture removed by the green crop by transpiration. The actual amount of water taken from the soil in this manner by a crop of *san* has been measured by Dr. Leather.

"It is interesting to note that a very markedly beneficial result on the wheat crop was obtained with *dhaincha* (*Sesbania aculeata*) at Motipur (as compared with that obtained with sunn-hemp at Pusa), some 40 miles west and north from Pusa, during the same season, although the *hathia* rain failed there also; it is possible that this result was due to the fact observed by Dr. Leather that the loss of water from the soil by transpiration is less with *dhaincha* than with sunn-hemp, thus affording a parallel case to that recorded by Voelcker with vetches and mustard at Woburn."

Another point brought out in this bulletin is the relatively small importance of the actual amount of nitrogen in the soil as compared with the form in which it exists, and the general trend of investigation suggested is in the direction of attempting to control, or even initiate, by permanent or occasional variation of the physical and chemical conditions, changes that convert the nitrogen in plant tissues, or in the residual

stock in the soil, into forms in which it is more or less available to the plant.

Dacca and Jorhat.

The special importance of Meggitt's work in Eastern Bengal and Assam lies in the fact that he has been dealing with acid soils, whereas that at Pusa contains over 30 per cent. of calcium carbonate.

In addition to the practical conclusions already referred to, his earlier experiments suggested important investigations into the effect of varying degrees of excess of acid or base in the soil, in connection with the application of phosphatic manures, on the growth and decay of the green manure crop and the growth of the primary crop. An account of the observations on which the suggestion was based is given by Meggitt in Appendix III of the *Annual Report of the Dacca Experimental Station* for 1911-12 cited above.

Work in connection with lime and phosphates on acid soils is being continued by Meggitt at Jorhat in Assam, and a Memoir[1] has since been published by him, which though not touching directly on the question of green-manuring is of interest in that connection as the work at Jorhat owed its inception to the failure of certain crops to survive the seedling stage during the *rabi* season—a failure "aggravated in one instance by the fact that a green-manuring crop had been grown and ploughed in the previous rains by way of preparation."

Central Provinces.

Allan's paper showing the intimate relation between the rainfall subsequent to ploughing in the green manure and before seeding the following crop, and the yield of that crop, has been referred to; it may be said to have established on a scientific basis as regards India, a theory put forward by many observers.

Coimbatore.

With the exception of analyses of various green manures published by Mann, Hope, Anstead, Coleman, Harrison, and others, the only other considerable scientific work that has been done in India in this connection is that of Harrison and Aiyer on the gases of swamp rice soils. The practical conclusions so far arrived at have been mentioned above (p. 30).

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[1] Studies of an Acid Soil in Assam. *Mem. Dept. of Agri. in India, Chem. Ser.*, Vol. III, No. 9.

Further investigations[1] published in December, 1914, have amplified the former work, and the results are summarized by the authors as follows :—

"(1) The organized film in contact with the surface of swamp rice soils utilizes the soil gases in such a manner as to bring about an increased oxygen output from the film, leading to a correspondingly increased root aeration.

"(2) The film contains bacteria which possess (1) the power to oxidize methane and hydrogen, and (2) to assimilate directly methane and carbon-dioxide. These changes either directly or indirectly result in the production of CO_2 which is in turn assimilated by the green algæ, with the evolution of oxygen.

"(3) The film may be looked upon as fulfilling the duty of an oxygen concentrator at a point which enables the maximum oxygen concentration to be produced in the water entering the soil.

"(4) The practice of green-manuring, by increasing the output of the soil gases, brings about an increased activity on the part of the film, resulting in an increased oxygen production and root aeration. An important indirect function, then, of green-manuring is to bring about a greater root aeration, and so induce greater root development and cropping power.

"(5) The oxygen concentration of the water entering the soil appears to be one of the main factors which regulate the growth of the crop."

Further experiments are in progress and the results of this promising line of investigation are eagerly awaited.

CONCLUSION.

In conclusion it may be said that the survey that has been attempted in this compilation, of the work that has been done and is in progress in India in connection with green-manuring, merely serves to show how much remains to be done. While on the one hand there has been considerable extension of the practice in cases where it is markedly profitable, and scientific work has been started, along several promising lines of investigation, on the other hand the details of field practice and the economics of the subject appear to be worthy of closer attention, with

[1] The Gases of Swamp Rice Soils, Part II. *Mem. Dept. of Agri., Chem. Ser.*, Vol. IV, No. 1.

reference to local agricultural conditions, than they have hitherto received.

In particular, the place occupied by leguminous food and fodder crops in the rotation appears to require study, with a view to ascertaining to what extent fertility is kept up by their means. The rise in prices of agricultural produce in India as compared with those of improved mechanical appliances and of manures, indicates a possible solution of the problem of the deficiency of organic matter in Indian soils by means of more intensive cultivation and irrigation, involving the production of a greater bulk of produce; and the question of the position of leguminous fodder and green-manuring crops in agricultural economy is likely to assume correspondingly greater importance.

PUSA.
April, 1915.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 57 1915

Agricultural Research Institute, Pusa

The Detection of Added Water in Milk in India

BY

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1915

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The Detection of Added Water in Milk in India.

The detection of added water in milk depends in Europe usually on the percentage of "solids-not-fat" that is the sum of the amounts of lactose, proteids and mineral matter. The milk is that of the cow and the percentage of solids-not-fat approaches 8·5 so nearly that this is considered a standard. The English law runs[1] "Where a sample of milk (not being milk sold as skimmed, or separated, or condensed milk), contains less than 8·5 per cent. of milk solids other than milk fat, it shall be presumed for the purposes of the Sale of Foods and Drugs Acts, 1875 to 1899, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk solids other than milk fat, or the addition thereto of water."

In India the milk sold in towns consists not only of cows' but also of buffaloes' milk and indeed usually it is largely the latter. The percentage of solids-not-fat in these is not identical, that of buffaloes' milk being generally greater.[2] The difference is principally due to a higher percentage of proteids in buffaloes' milk. The largest series of milk analyses which have been published are those by Meggitt & Mann[3] from which the following average percentages are deducible:—

	No. of animals	No. of samples	Solids-not-fat %
Gir cows' milk . . .	4 to 8	26	8·95
Sind cows' " . . .	4 to 12	112	9·41
Surti buffaloes' milk . .	6 to 18	68	10·37

These samples were the mixed milks of a number of animals in each case as shown in the statement.

[1] *Sale of Milk Regulations*, 1901.
[2] Leather, J. W. *The Analyst*, 1901.
[3] *Mem., Dept. Agri. in India, Chem. Ser.*, vol. II, nos. 1 and 4.

The mean percentage found for the milk of the Montgomery cows at Pusa is 8·79. There is thus a wider range of percentage of solids-not-fat in Indian than in English milks, and since there is no means of ascertaining the respective proportions of buffalo and cow's milk when mixed, if dependence is placed on the proportion of solids-not-fat as a means of detecting added water, we would have to adopt a figure which would not be too high for cows' milk alone. Such a figure would be say 8·8 and the seller of buffaloes' milk might add some 18 per cent. of water and still sell a milk containing the required percentage of solids-not-fat. A more reasonable standard would be based on the assumption that the milk sold in Indian towns is always at least one half buffaloes' milk. On this assumption the mean percentage of solids-not-fat has been calculated from the 68 buffaloes' milks, 26 Gir cows' milks and 42 of the Sind cows' milks as published by Meggitt and Mann. This mean percentage is 9·83. The probable error deduced from these 136 samples is $\pm$ 0·444, and the probability is 100 : 1 that any milk found to contain less than 8·10 per cent. solids-not-fat contains added water. The variation or error $\pm$ 0·444 is naturally high because of the considerable difference between the general composition of the cows' and buffaloes' milks respectively as well as because of the natural variations among the milks of the same class. Supposing such a standard as 9·83 per cent. to be adopted, it still leaves it open to the buffalo milk vendor to add some 10 to 20 per cent. of water without fear of detection.

Latterly, attention has been directed to the value of two other characteristics of milk for the detection of added water. The one is the refractive index of the milk serum, the other is the freezing point of the milk.

The former has not been used in this laboratory, but judging by published data[1] this method would hardly detect 10 per cent. of added water.

The latter method, that which depends on the freezing point of the milk, is more dependable, and has been used rather extensively,[2]

[1] Leuch and Lytagoe. *J. Am. Chem. Soc.*, 1904, XXVI, 1195.
[2] Beckmann, E. *Milch Zeitung*, 1894.
Beckmann and Jordis. *Forschungs-berichte uber Lebensmittel*, 1895.
Winter, J. *Les nouveaute's chimique*, 1905, p. 276.
Ducross and Imbert. *Bull. Sciences pharmacal*, 1905.
Cornalba, J. "On the milks of Lombardy" *Chem. Zeitung*, 1907-09.
Barthel. *Methods used in the examination of milk and Dairy Products*, 1910.
Leather, J. W. *The Analyst*, XXXIX, p. 432.
Hummilinck, M. G. *Chem. weekblad* (1914) XI, 207.
Van Raalte. *Chem. weekblad* (1914) XI, 206.
Reicher, L. T. *Chem. weekblad* (1914) XI, 323,

resulting in proof that the freezing point of pure milk varies so slightly that quite small additions of water can be readily detected. Thus:—

Winter and Parmentier found	−0·54 to −0·57° C.
Cornalba	−0·55 to −0·56° C.
Beckmann and Jordis	−0·554° C.

The Queensland Government has adopted the following standard for milk. "Milk shall be the normal, clean, and fresh secretion obtained by completely emptying the udder of the healthy cow properly fed and kept, excluding that got during fifteen days immediately before, and ten days immediately following on, parturition. It shall contain not less than eight and five-tenths per centum of milk solids-not-fat, three and three-tenths per centum of milk fat, and not less than twelve parts per centum of total solids; its freezing point shall not be higher than 0·55° C. below zero."

During the last two years opportunities have been taken of ascertaining the freezing point of genuine milks at Government dairies in India, most of the samples being those of single cows or buffaloes, and whilst I have found a considerably greater variation than most other observers, still the test remains very much more reliable for the end in view than that of the percentage of solids-not-fat.

The freezing point of milk is due to the several constituents which are soluble in water, those which are insoluble such as the fat, exercising no influence on it. The effect of the water-soluble constituents is readily exemplified from the following:—

	F.P. °C.
1. Proteids, casein and albumen, 3·3 per cent. in milk or 3·82 per 100 grm. water	−0·007
2. Lactose, 4·7 per cent. or 5·44 per 100 grm. water	−0·342
3. Phosphate, 0·25 per cent. or 0·29 per 100 grm. water; assumed to be 50 per cent. ionized (one half the phosphorus is assumed to be present in the proteids)	−0·068
4. Chloride, 0·25 per cent. or 0·29 per 100 of water; assumed to be 86 per cent. ionized	−0·149
sum	−0·566

In this estimate mean figures are naturally employed, and the constitution of the phosphate and chloride solution has been based on certain assumptions which are admittedly not very well estab-

lished.[1] Moreover the proportion of each constituent varies in milks, which necessarily causes a variation of freezing point. For example I have found the lactose to vary in Indian milks from 4 to 5 per cent., which alone would affect the freezing point considerably.

The estimated effect of the several constituents is, however, quite sufficient for our purpose. It shows that the effect of the casein and albumin is so small that variation in the percentage of these would affect the freezing point in only a minor degree. This alone provides a reason for expecting the milk of the buffalo to have a freezing point similar to that of the cow, because the difference between the percentage of water-soluble constituents of these two milks is chiefly due to a higher percentage of proteid in the former. The estimated effects on the freezing point also show why a variation greater than that found by some investigators is to be expected, for the expected variation in percentage of milk sugar alone would account for this.

In the following Table I are set out the freezing points of the milks which have been tested in India.

It will be seen that the individual variations are considerable, but in making this comparison it is to be recollected that the samples have been mostly those of single animals, whereas the milk sold in towns is the mixed milk of a number, in which the variation is naturally less.

The mean freezing point of all these 77 samples, excluding pasteurized and separated milk and colostrum, is $-0{\cdot}542°$ C. and the probable error $= \pm\ 0{\cdot}00907$. This mean figure is somewhat lower than that adopted in Queensland as the standard, but is not seriously different.

The effect on the freezing point of adding water to milk is substantially linear, and it may be expressed by the equation.

$$W = ax$$

where W = added water,

x = F. P. of pure milk minus that of the sample,

a = a constant.

There are two modes of expressing the added water; (*i*) as a percentage of added water *in* the sample, in the same sense as one employs the term to express the proportion of butter fat, or (*ii*) as

[1] Richmond, H. D. *The Analyst* (1902), XXVI, p. 241.
Allen, A. H. *Commercial Organic Analysis*, second edition, vol. IV, p. 103.

Table I.

Freezing points of milks of Indian Cows and Buffaloes.

Pusa		Lyallpur		Peshawar		Lucknow		Ambala	
Cows.	F. P. °C.	Cows.	F. P. °C.	Cows.	F. P. °C.	Cows.	F. P. °C.	Cows.	F. P. °C.
Saniwal breed.		*Saniwal breed.*				*"Harriana."*		*Saniwal breed.*	
Begmini	−0·557	A	−0·546	No. 72	−0·541	Bella	−0·543	No. 1060	−0·523
Bhamini	−0·568	B	−0·543	No. 46	−0·549	Anu	−0·540	No. 817	−0·532
Kaveri	−0·572	C	−0·534	No. 219	−0·529	Agata	−0·527		
				Buffaloes.				*Ayrshire-Hissar.*	
Jamini	−0·577	D	−0·541	No. 13	−0·532	Grace	−0·536	No. 191	−0·532
Godhi	−0·567	E	−0·543	No. 1	−0·554	Cowslip	−0·544	*Ayrshire-Saniwal.*	
Mukhia	−0·553	F	−0·562	No. 76	−0·564	*Saniwal.*		No. 845	−0·529
Boudhi	−0·543	G	−0·544	No. 6	−0·542	Basanta	−0·527	No. 861	−0·540
Jardi	−0·566	H	−0·545	No. 35	−0·532	Archi	−0·534	No. 236	−0·546
Bhootki	−0·561	I	−0·545	No. 56	−0·546	Kathwal	−0·524	No. 105	−0·543
Rajni	−0·570	J	−0·527	No. 73	−0·539	*Ayrshire-Harriana.*		No. 946	−0·530
Buffaloes.		K	−0·530	*Mixed milk.*		Ruchar	−0·535	No. 106	−0·533
No. 1	−0·545	L	−0·542	Cows	−0·537	Queen Mary	−0·537	No. 204	−0·545
No. 2	−0·544	*Mixed milk.*		Buffaloes	−0·552	*Buffaloes-Murrah.*		*Buffaloes.*	
Mixed milk.		Cows	−0·547			Judas	−0·562	No. 416	−0·554
Cows	−0·555					Aggie	−0·518	No. 33	−0·544
,,	−0·549					Hope	−0·527	No. 464	−0·546
						Curtes	−0·527	*Mixed milks.*	
						Cherry	−0·535	Cows	−0·535
						Nigram	−0·521	,,	−0·524
						Rukhee	−0·518	Buffaloes	−0·529
						Muttra	−0·526	,,	−0·531
						Mixed milk.		*Pasteurized milk.*	
						Cows	−0·544	Cows	−0·536
						Buffaloes	−0·530	Buffaloes	−0·544
								Separated milk	−0·579
								Do.	−0·519
								Colostrum	−0·543

so and so much water added to 100 parts of milk. The difference between these two modes of expression may be illustrated by the somewhat extreme case of a pint of water being added to a quart of milk. If the water is expressed as a percentage *in* the sample, it

is 33 per cent.; if as a percentage of water added *to* the milk it is 50 per cent. (approximately). Either mode is correct provided it is clearly stated, but the former is more in consonance with that generally employed in analytical chemistry, and is adopted here.

In respect of the freezing point of pure milk one must take the best average figure at our disposal, which is $-0{\cdot}542°$ C. The value of a in the equation has been estimated from the freezing points of a series of portions of the same milk to which different (known) quantities of water had been added. This series of tests yielded

$$a = -172.$$

The value of a deduced from Winter's Table is $a = -176$.

The difference between the two is immaterial and -174 may safely be taken as a good value. The equation then becomes

$$W = -174\ (-0{\cdot}542 - t)$$

where t is the freezing point of the sample. If then t is found to be, say, $-0{\cdot}520$, the percentage of added water in the milk is $-174 \times [\,-0{\cdot}542 - (-0{\cdot}520)\,] = -174 \times -0{\cdot}022 = 3{\cdot}83$.

A freezing point of $-0{\cdot}520$ is one of the lowest which I have met with. However, judging by the probable error whch accompanies the mean value $-0{\cdot}542°$ C., a freezing point of $-0{\cdot}507°$ C. is possible once in a hundred times in the case of the milk of a *single* cow or buffalo; such a case would indicate

$-174 \times [-0{\cdot}542 - (-0{\cdot}507)\,] = 6{\cdot}1$ per cent. added water.

Such a case is not to be expected from mixed milks; the probability is too remote.

It has, however, to be realized that any dairyman who waters his milk will not add so little as 5 per cent.; it is unlikely that he would add less than some 10 to 20 per cent. which assumption makes it quite certain that adulteration with water can be detected by the chemist with certainty, except in the improbable case of less than 5 per cent. being added. The method is obviously very much more certain than the deduction from the percentage of solids-not-fat.

With reference to the method of ascertaining the freezing point, little explanation is required in addition to the details commonly employed in cryoscopic determinations. I find it best to employ a bath of ice and salt solid, and to place the milk in a tube which is itself in an outer empty tube, the latter being in contact with the bath. The temperature of the milk usually supercools from $1\frac{1}{2}°$ to $2°$; as soon as ice commences to form, the temperature rapidly

rises to the true freezing point. I allow half-a-minute to elapse between each reading of the thermometer, and at the freezing point the variation of temperature is not more than 0·002° C. The thermometer should be steady within this limit for at least two minutes.

The following Table II exhibits the percentage of added water corresponding to the freezing point of the sample.

TABLE II.

Percentage of added water corresponding to the freezing point of the sample.

Freezing point °C.	%	Freezing point °C.	%	Freezing point °C.	%
−0·542	0·00	−0·442	17·40	−0·342	34·80
−0·537	0·87	−0·437	18·27	−0·337	35·67
−0·532	1·74	−0·432	19·14	−0·332	36·54
−0·527	2·61	−0·427	20·01	−0·327	37·41
−0·522	3·48	−0·422	20·88	−0·322	38·28
−0·517	4·35	−0·417	21·75	−0·317	39·15
−0·512	5·22	−0·412	22·62	−0·312	40·02
−0·507	6·09	−0·407	23·49	−0·307	40·89
−0·502	6·96	−0·402	24·36	−0·302	41·76
−0·497	7·83	−0·397	25·23	−0·297	42·63
−0·492	8·70	−0·392	26·10	−0·292	43·50
−0·487	9·57	−0·387	26·97	−0·287	44·37
−0·482	10·44	−0·382	27·84	−0·282	45·24
−0·477	11·31	−0·377	28·71	−0·277	46·11
−0·472	12·18	−0·372	29·58	−0·272	46·98
−0·467	13·05	−0·367	30·45	−0·267	47·85
−0·462	13·92	−0·362	31·32	−0·262	48·72
−0·457	14·79	−0·357	32·19	−0·257	49·59
−0·452	15·66	−0·352	33·06	−0·252	50·46
−0·447	16·53	−0·347	33·93	−0·247	51·33

PUSA,
August 1915.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Bulletin No. 58

1916

Agricultural Research Institute, Pusa

Calocoris angustatus, *Leth.*

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CALOCORIS ANGUSTATUS, *Leth.*

Calocoris angustatus is a member of the family Capsidæ, sub-family Capsinæ, Division Phytocoraria. The following description is taken from Distant, *Fauna of India, Rhynchota,* Volume II, page 452.

"*Calocoris angustatus,* Leth., *Ind. Mus. Notes,* III, No. 2, page 90 (1893), fig.

Very elongate; dull flavescent; antennæ fulvous, first joint robust, as long as the head, second joint very long, slender, four times as long as first, third, fourth and fifth joints equal, slender, equal in length to the first joint; pronotum trapeziform, punctulate, posterior angles somewhat prominent, slightly obtusely acute, anterior angles obtuse, anteriorly with a distinct collar, the apical area for about one-third from anterior margin robustly callose; hemelytra flavescent, punctate, sparingly fulvous-pubescent; clavus and sutural portion of corium roseate, sometimes concolorous; legs concolorous, tibiæ armed externally with ten or eleven black spinules; apices of tarsi fuscous. (Lethierry.) Length 6 to 7 millim. Hab. Madras.

Stated to injure *cholam* (*Sorghum vulgare*) in the South Arcot District of the Madras Presidency."

Calocoris angustatus, Leth., is to be found all over Southern India as a pest of *cholam* (*Andropogon Sorghum*). It seems to have been first reported as damaging this crop from South Arcot in 1891. In *Indian Museum Notes,* Part 2 of Volume III, p. 90, 1893, it was described as a new species by M. Lethierry. It has been recorded as a pest at intervals ever since.

The amount of damage which it does varies considerably in different seasons and in different places, but it must unquestionably be placed among the major pests of *cholam.* When in large numbers the loss caused to the crop is considerable as the blackened ear heads and shrivelled seeds in a badly infected field amply testify. Previous references are to be found in *Indian Museum Notes, Fauna of India,* page 452, Lefroy's *Indian Insect Life* page 707, and *Some South Indian Insects,* page 490.

The female can be distinguished from another very similar Capsid frequently found in company with it (*Megacœlum stramineum*) by the length of the ovipositor. In the case of the associated Capsid, the ovipositor when folded into the body, is short and black, while in *C. angustatus*, when retracted, it reaches forward through five segments (fig. I).

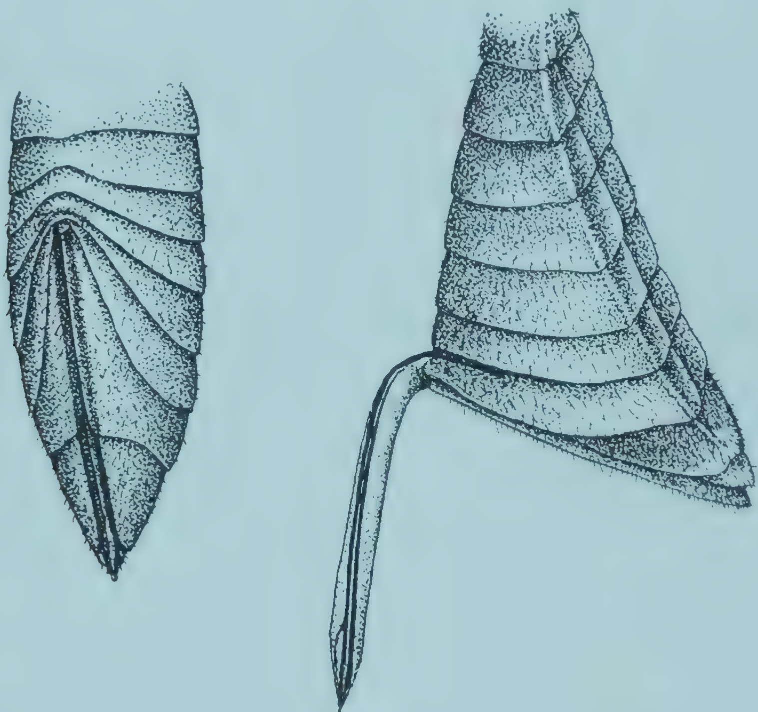

Fig. 1. Extremity of abdomen of *Calocoris angustatus* showing ovipositor extended and retracted.

In Tamil districts it is known together with two other Capsids and *Nezara viridula* as *Navai puchi*. In Telugu districts the adult bugs are known as *Patcha purugu*, (green insect) and *Yeesa purugu*, while the nymphs are called *Yerra purugu* (red insect) and *aggi-purugu* (fire-insect).

C. angustatus has been found on a variety of other cereals and grasses such as Cumbu (*Pennisetum typhoideum*), Thenai (*Setaria italica*), Maize (*Zea mays*) and Abyssynian grass (*Eragrostis abyssinica*). It is probably a very minor pest of these and it is to *cholam* alone that any great damage is done.

Life History.

Calocoris makes its appearance as soon as the young ear heads begin to push their way out of the enfolding leaf sheath. In the young florets the eggs are laid inserted under the glumes or into the middle of the floret

by means of the long scimitar-shaped ovipositor. By the time the ear heads are quite free, it is always possible to shake out the crowds of young nymphs with the orange-red colour characteristic of the first immature stages. When the young grains are just in the "milk" stage, is probably the time when the most damage to the crop is done. The continual sucking of myriads of nymphs and adults at this time causes the grain to shrivel and often the whole ear head is seen dry and blackened.

Eggs are never laid in seed which is set and, when the grains are hard, it is only the young and immature grains that are chosen as being suitable for oviposition.

The Egg.

The egg is cigar-shaped, tapering slightly more towards the lower end than at the top. The top is closed by a lid fitting into a raised rim. In some lights the egg is iridescent, but its usual appearance is a very beautiful torquoise-blue although some eggs are very pale or almost colourless.

The eggs are usually laid in numbers varying between 1 and 16 in each floret. The place of oviposition is either between the inner and outer glumes or in the very centre of the floret between the pollen sacs. The more usual place is between the inner and outer glumes. In the Insectary, oviposition always took place at night, and began from two to three days after pairing.

Females were never observed ovipositing in the field. It is probable, therefore, that eggs are laid at night under natural as well as under artificial conditions. The time of incubation for the eggs is from five to seven days. Seven days is rather exceptional, six days being the most usual period. As the embryo develops, the egg undergoes certain colour changes, first becoming greenish, then yellow and finally a day or two before hatching it is a bright orange colour.

At first great difficulty was experienced in getting the eggs to hatch in the Insectary. It was eventually found that an extremely moist atmosphere was necessary for their well-being. This was attained by keeping the eggs, either free or in their florets, in a tube plugged with cotton-wool. This tube was placed in a glass stoppered air-tight jar, with wet sand. Eggs hatched in this way took the same time as "controls" laid in florets in the field.

The number of eggs capable of being laid by each female is not very satisfactorily established. The greatest difficulty was experienced in

keeping bugs alive for long enough to enable them to lay their full quota of eggs or what was imagined to be their full quota. The disease to be referred to again hereafter accounted for fully 80 per cent. of the bugs which had been selected for studying their egg-laying record.

Some others appeared to die a natural death, if one may so term it, after laying comparatively few eggs. This however may actually occur in the field. Below are given some of the more successful records obtained :—

Number of insects	Number laid	Dates between which eggs were laid
1	69	19-XI-1914 and 29-XI-1914
2	132	19-XI-1914 „ 30-XI-1914
3	217	12-XI-1914 „ 26-XI-1914
4	175	12-XI-1914 „ 26-XI-1914
5	86	13-XI-1914 „ 22-XI-1914
6	72	13-XI-1914 „ 20-XI-1914
7	83	18-VIII-1914 „ 30-VIII-1914
8	129*	16-IX-1914 „ 2-X-1914
	963	

* Dead of disease.

The average in natural circumstances probably lies between 150 and 200. Egg-laying occupies probably not more than 14 days. No eggs are laid in grain which has set. Only the young unfertilized flarets seem to be chosen.

The nymphs.

The nymphs emerge from the eggs from five to seven days after oviposition. They leave the eggs by pushing their way out at the top through the lid referred to above.

I. Instar (Plate, fig. 3): The length of the newly hatched nymph is 1·4 mm. The thorax is yellowish, and the segments thereof

very distinct, the abdomen is uniformly orange-red, the eyes are red. The tarsi and tip of the proboscis are black. The proboscis reaches to the last pair of coxæ.

II. Instar: The orange colour has either entirely disappeared or become much paler. The length of this stage is 2 mm.

III. Instar (Plate, fig. 4): The nymph is a light greenish-yellow and 2·5 mm. in length. The orange colouring is in general concentrated in one spot on the 3rd segment of abdomen.

IV. Instar (Plate, fig. 5): The wing pads first make their appearance at this stage. The measurements of this instar vary between 3·3 and 3·7 mm. The nymphs are now green in colour.

V. Instar (Plate, fig. 6): The wing pads at this stage become dark in the case of male nymphs, but remain green in the case of females.

After the fifth moult, the insects assume the adult form. The males (Plate, fig. 7) are rather smaller than the females (Plate, fig. 8) and the clavus and membrane are suffused with dark brown.

The first moult takes place three days after the eggs have hatched, after that a moult takes place as a rule every 2 days.

Examples are given below :—

A. ♂ hatched	23-24-XII.
No. of moult	date
I	26-27-XII.
II	28-29-XII.
III	30-31-XII.
IV	1-2-I.
V	3-4-I.
B. ♀ hatched . . .	23-24-XII.
I	27-28-XII.
II	29-30-XII.
III	31-XII-I-I.
IV	2-3-I.
V	4-5-I.

The total length of the life-history from egg to adult occupies between 15 and 17 days.

Examples taken from among the many life-cycles which were studied.

	Date on which eggs were laid	Date of hatching	Date on which insect became adult	Total
A	28-29-VIII	3-4-IX	13-14-IX	17 days.
B	27-28-VIII	3-4-IX	11-12-IX	15 ,,
C	24-25-VIII	30-31-VIII	8-9-IX	15 ,,
D	23-24-VIII	29-30-VIII	8-9-IX	16 ,,
	23-24-VIII	29-30-VIII	9-10-IX	17 ,,

A Calocoris female, provided that she is fertilized on the same day as that upon which she assumes the adult form, may therefore be ready to lay eggs within three weeks of the date when she was herself but an egg.

This would give at least two generations on one crop of *cholam* since all ears do not ripen at the same time. When no *cholam* is available, probably grasses supply the necessary food until such a time as there is young *cholam* to be had once more.

Natural enemies.

So far all efforts to find parasites or predators of Calocoris have proved unavailing. There is only one natural check on increase that is known and it is doubtful whether this affects the insect under natural conditions.

In the Insectary, as has already been stated, there was heavy mortality among the adult insects kept for egg-laying. In nearly every case of premature deaths the symptoms were the same, rather resembling "pebrine" in silk worms.

The first symptom is the cessation of egg-laying; one or two days later the insect will be found dead in its jar. It becomes very soft and flabby and discoloured. The discoloration proceeds from anteriorly backwards. The whole body can be disintegrated, the legs and antennae easily parting from the body. These symptoms are accompanied by an extremely evil smell like decaying cheese.

Mr. W. H. Harrison, Government Agricultural Chemist, very kindly undertook to make cultures from dead insects and a bacterium was isolated and grown. With this culture, experiments were made to prove whether the isolated bacterium was the one responsible for the deaths. Individuals of Calocoris were let into two jars. In one, the sides of the jar were smeared with the culture and in the other, the food (*cholam* grains) was also smeared. In each case, the bugs died after a short time showing all the usual symptoms.

These experiments were not persisted with in detail and are therefore quite inconclusive. It made no difference to the chances of a bug's escape from the disease if it had been reared in the Insectary or brought in from the field. Every precaution was taken to see that jars in which insects were kept were sterilized as far as it was possible and forceps were rendered antiseptic. It is possible that bugs contracted the disease from the ear heads upon which they were fed. In no case did any nymphs die of this disease, which seemed entirely confined to the adults.

If a dead insect were left in the breeding jar with another healthy one, this in the course of two or three days almost invariably contracted the disease and died.

Artificial control.

Various remedies have been suggested from time to time for the control of this pest varying from spraying to catching them with nets. Most of them are impracticable and the proper remedy is still to be discovered.

Spraying is, of course, quite out of the question and need not be discussed further. Another remedy suggested was to dip the ear heads in a tin of kerosine emulsion, the idea being that in this way the nymphs would be reached by the emulsion and destroyed. This would only be a possible remedy where the *cholam* was of a small variety and while it was young and supple.

The best method, so far suggested, is that of shaking the ear heads over a tin or pan containing water with a film of kerosine floating on top. In this case, again, it could only be practised while the *cholam* stems were young and sappy.

Light trap experiments proved fruitless. A simple remedy which will appeal to the ryot is still to be found. It may be that the remedy

will be arrived at by taking advantage of some tropism, or by methods purely agricultural. At present one can suggest nothing and the pest must be left in undisturbed possession of the crops upon which it has fixed for the scene of its ravage.

COIMBATORE,
March, 1915.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

Calocoris angustatus.

Fig. 1.	Egg in natural position,	× 6.
„ 2.	Eggs,	× 20.
„ 3.	First instar,	× 16.
„ 4.	Third „	× 10.
„ 5.	Fourth „	× 10.
„ 6.	Fifth „	× 8.
„ 7.	Adult, male,	× 10.
„ 8.	„ female,	× 10.

Calocoris angustatus.

Bulletin No. 59 1916

Agricultural Research Institute, Pusa

One Hundred Notes on Indian Insects

BY

T. BAINBRIGGE FLETCHER, F.L.S., F.E.S., F.Z.S.

Imperial Entomologist.

SEP 6 1916
LAL-BAGH, BANGALORE.

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PREFACE.

THIS Bulletin contains a collection of one hundred short notes on Indian Insects, their names, habits, lifehistories and occurrence either in previously unrecorded localities or on new foodplants. Such notes are commonly made by workers in all branches of entomology but are usually buried away in note-books, reports, and files, or, if published, are so scattered that in any case they become inaccessible to the ordinary student. To obviate this, it is proposed to issue similar notes, collected to form Bulletins, which will be published as material accumulates, and any such notes should be forwarded to me for inclusion in the series. They may deal with habits, lifehistories, foodplants or any other particulars regarding Indian Insects, whilst notes on new crop-pests and on actual trials of control methods are especially required; but in all cases the insects must be properly identified.

I am indebted to Mr. G. J. Arrow for the identification of the insects mentioned in Notes Nos. 3-25, to Mr. G. A. K. Marshall in Notes 27-30, to Mr. E. Brunetti in Notes 39-60 and to Mr. E. Meyrick for most of those in Notes 74-92.

T. BAINBRIGGE FLETCHER,
Imperial Entomologist.

PUSA:
29th September 1915.

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LIST OF FIGURES.

One Hundred Notes on Indian Insects.

1. Fauna of a rotten Papaya stem.

IN July 1914 I examined the stem of a dead Papaya (*Papaya carica*) which was standing in my garden at Pusa. The whole interior consisted of a wet mass of rotten pulp which contained numerous dipterous and coleopterous larvæ. Amongst the Diptera bred out were long series of *Stomoxys calcitrans* (Muscidæ), *Clitellaria heminopla*, W., and *Wallacea argentea* (Stratiomyiadæ) and amongst the Coleoptera were *Lasiodactylus* sp. (Nitidulidæ), a Histerid, *Belonuchus quadratus* (Staphylinidæ), another Staphylinid beetle, and *Monomma brunneum.*

The Tineid moth, *Dasyses rugosella*, has also been bred at Pusa and Coimbatore from Papaya stems, the larva feeding on rotten wood.

2. Formation of new colonies of Oecophylla smaragdina.

The nests of *Œcophylla smaragdina* are usually commenced by a single female which lays a batch of eggs on a leaf which is generally more or less curled up or folded over to provide some degree of shelter. When at Myitkyina, in Upper Burma, in August 1914 I found a terminal shoot of *Hibiscus rosasinensis* occupied by an incipient colony composed of eight deälated females and a common mass of eggs and larvæ. No males or workers were present, but the leaves were fastened together with silk to a slight extent. The foundation of a new nest by two or more queens acting in common seems to be a very unusual circumstance.

3. Glycyphana horsfieldi, Hope. (Arrow, F. I. Ceton., page 121.)

A specimen of this beetle was collected by me at Santikoppa in North Coorg in May 1914 and has been named by Mr. Arrow. The species is not definitely recorded from Southern India in the "Fauna" volume. In this Coorg specimen the golden patches are large, as in the Ceylon form.

4. Protaetia maculata, Fab.

A specimen taken by myself at Coimbatore on 18th September 1913 has been returned by Mr. Arrow under this name. In the "Fauna" volume on Cetoniadæ this is referred to (pages 143-144) as *aurichalcea*, Fab.

5. Protaetia terrosa, G. & P. (Arrow, F. I. Ceton., pages 157-158.)

Two specimens collected in Bellary in September 1913 and identified by Mr. Arrow. This species does not seem to have been recorded previously from Southern India.

6. Spilophorus cretosus, Hope. (Arrow, F. I. Ceton., pages 201-202, f. 45.)

A specimen was taken by myself on *Cordia subcordata* at Coimbatore on 8th December 1913, and has been identified by Mr. Arrow, who only records it in his " Fauna " volume from Bengal, Bombay and Ceylon. A second specimen was taken on *cumbu* at Coimbatore on 21st September 1909, and we have it also from Chapra in Bihar.

7. Eupatorus gracilicornis, Arrow. (Trans. Ent. Soc. London, 1908, 351 ; F. I. Ceton., and Dynast., page 270.)

One female in Pusa collection, collected at Masuri on 1st September 1906, has been identified by Mr. Arrow as this species. In the " Fauna " volume it is recorded only from Assam (we have it from the Khasi Hills), Burma, Siam and Tonkin.

8. Eophileurus planatus, Arrow. (F. I. Ceton. and Dynast., pages 288-289.)

Five larvæ of this beetle were found at Pusa on 19th May 1915 at the base of a Gular tree (*Ficus glomerata*) in a place where some dead uprooted grass was mixed with the soil. At this time the larvæ were about 35 mm. long, in general appearance like *Oryctes* grubs, the head red-brown, shiny, and with the surface minutely pitted, tips of mandibles black, antennæ red-brown and legs brownish-yellow. They fed up on farmyard manure in the Insectary until 24th July, when one was found to have pupated and the beetle emerged on 2nd August, by which date two of the other grubs were found to have attained the adult stage also. The fourth specimen, which had already pupated on 25th July, emerged on 4th August. Pupation takes place in a spacious earthen cell specially formed underground, the pupa being enclosed in the larval skin as in the case of *Anomala*.

We have this beetle also from Pusa (April 1907, in bark of tree, and 30th April 1914), from Dacca (15th January 1906 and 27th July 1911), and from Triperri (20th March 1905 ; in a mango trunk).

9. Pentodon bispinifrons, Reitt. (Arrow, F. I. Ceton. and Dynast., page 303.)

The distribution of this species extends considerably further south than is indicated in the " Fauna " volume. We have it from Lyallpur

(at light, 10th June 1906 and 17th August 1911), Simla (July 1909, Carson Coll.), Baroda (Sugarcane, 17th August 1907), Chapra, Bihar, (Mackenzie Coll.), and from Pusa (23rd June 1905, in cane field; April 1909; at light on 4th December 1905; June 1907; June 1910; 19th August 1908).

10. Holotrichia conferta, Shp.

Two specimens collected on Coffee, Santikoppa, Coorg, 10th April 1912, by R. D. Anstead, have been identified as this species by Mr. Arrow.

We also have it from the Nilgiris (Pykara, 6,000 feet, May 1911, Andrewes Coll.) and it is one of the various Cockchafers which appear in Ootacamund after the showers in April and May. The species is figured in *South Indian Insects*, fig. 68, No. 9.

11. Brahmina coriacea, Hope.

This beetle has been sent in on two occasions, on 30th June 1910 and 1st July 1912, by the Superintendent of the Government Garden at Jeolikote, Kumaon, who reported that the beetles suddenly appeared in large numbers and fed during the night on leaves of vine, fig, apple, pear and plum, devouring the portions of the leaves between the veins. They were particularly destructive to the leaves of vine and apple, and were associated with *Adoretus versutus* and *A. horticola.*

12. Anomala bengalensis, Bl.

Three specimens bred from larvæ in leaf-mould at Pusa, April-May 1910. (C. No. 831).

The larvæ were found in June 1909 feeding on leaf-mould in a pit, which had been specially made and filled with leaf-mould for the purpose of planting avenue trees. The full-grown grub was about 40 mm. long and about 8 mm. broad, of the usual shape of Melolonthid larvæ, in colour pale-yellow, the posterior two segments blackish owing to intestinal contents, the head yellow-brown with the apical half of mandibles black; on the segments were longish brown hairs scattered over dorsal and ventral surfaces and also some very short spinous hairs on the back of the first six abdominal segments and on the tip of the anal segment; spiracles yellow-brown, strongly crescentic in shape, the crescent directed posteriorly on prothorax and anteriorly in the case of the abdominal spiracles. The adult beetles emerged on 20th April, 5th May and 19th May 1910.

The beetle is very close to *A. varians* with which it has been confused hitherto but its comparatively shorter and broader size and slightly

excised clypeus distinguish it from *A. varians*, in which latter species the clypeus is evenly rounded.

13. Anomala (Pseudosinghala) transversa, Brsk.

This species was very common at Shillong, in the Khasi Hills, in May 1905, being found on cherry as a minor pest. A note made at the time reads :—" Above 4,000 feet these beetles come out of the ground in enormous numbers by day and feed on white flowers, roses, Spiræas, etc. Black and yellow-spotted [individuals] couple together and appear to be one species. Caught at white cloth in large quantities but not at light."

A series of thirty-five specimens reveals a considerable range of variation. The normal form is black with a broad irregular transverse orange band across the centre of anterior half of each elytron, but entirely black specimens are almost equally common, whilst in other cases the orange markings may extend over the whole, or almost all, the surface of the elytra.

14. Minor Pests of Peach at Maymyo.

Two Rutelid beetles, collected at Maymyo in Upper Burma on 17th and 18th May 1909, by K. D. Shroff, Entomological Assistant, as attacking leaves of Peach (*Prunus persica*) have been identified by Mr. Arrow as *Anomala aurora*, Arrow, and *Anomala pallidospila*, Arrow.

The Pusa Collection contains a co-type each of *Anomala aurora* and *Anomala pallidospila*, collected by Mr. H. L. Andrewes at Maymyo in May 1910.

15. Adoretus limbatus, Bl.

Fairly common at light at Pusa in June. We have it also from Katihar, Bengal (ex Ind. Mus. Coll.) and from Toungoo (ex Andrewes Coll.). This is a small dark-coloured species, with a distinct pale longitudinal stripe bisecting each elytron, sides of thorax and costal edge of elytra broadly yellowish.

16. Adoretus ovalis, Bl.

We only have this from Ootacamund (9th April 1901 ; Barber Coll.). It is figured in *South Indian Insects*, fig. 127.

17. Adoretus bicaudatus, Arrow MS.

The Pusa collection contains a single example of this beetle, sent in on 12th October 1908 by Mr. C. E. Presley from Fenchuganj in Sylhet, with a note stating that " the leaves of nearly all the trees, roses and others, in the garden at Fenchuganj appear like lace, they have been so thoroughly eaten away by these beetles.

18. Adoretus lasiopygus, Brsk.

This appears to be the commonest species of *Adoretus* in the Pusa District and is probably the species usually responsible for damage to leaves of garden plants between June and September. The adult beetles come fairly freely to lights at night.

We also have it from :—

Calcutta (Ind. Mus. Coll.) ; Begum Serai, Bengal, 22nd July 1904 ; Daltonganj, Bengal, August 1905, on Cucumber (C. S. Misra) ; Palamau, Bihar, September 1906 ; Chapra, Bihar (Mackenzie) ; Jorhat, Assam, 29th June 1907 ; and Rewari, Punjab, 4th October 1905 (C. S. Misra).

At Begum Serai it did serious damage to vines and, after absolutely stripping the vines of every leaf, the beetles attacked the fresh shoots.

19. Adoretus caliginosus, Brsk.

We have this from Pusa (6th June 1908, and at light on 1st July 1914), from Jorhat in Assam (29th June 1907 ; captured in association with *A. lasiopygus*), from Jalalpur in the Surat District of Bombay (5th May 1904), and from the Bababudin Hills in Mysore (April 1913).

20. Adoretus versutus, Har.

This seems to be a common species around Calcutta, whence we have specimens taken at night on *Lagerstrœmia* in the compound of the Indian Museum. We also have specimens from Jorhat, Assam (29th June 1907), from Chapra in Bihar (Mackenzie Coll.) and from Pusa (31st July 1905, 1st July and 26th September 1907 and 13th October 1908), where it seems not to be very common and to occur later in the year than most other species of *Adoretus*. It was also found attacking leaves of vine, fig, apple, pear and plum at the Kumaon Government Gardens in June 1910 and 1912 in association with *Adoretus horticola* and *Brahmina coriacea*. It is probably common throughout the Plains of India.

This is the species referred to under the name *Adoretus bangalorensis* in *Indian Museum Notes* and *South Indian Insects* and it may again be pointed out that the figures of this species and of *Adoretus caliginosus bicolor* were originally transposed by error in *Indian Museum Notes* and that this error was repeated in *South Indian Insects*, so that figure 126 in the latter publication represents *A. versutus*.

A partial reference to literature will be :—

Adoretus versutus, Harold, Coleopt. Hefte V. 124 (1869) ; Kolbe, Mitt. Zool. Mus. Berlin, V. 22 (1910) ; Scott, T. L. S. XV 235, t. xii, ff. 10—12 (1912).

Adoretus vestitus, Boheman, Eugenies Resa II i 56 (1858) [*nec* Reiche].

Adoretus insularis, Fairm., Ann. S. E. Belg. XLI, 105 (1897) ; Alluaud, List Coleopt., p. 271.

Adoretus bangalorensis, Brenske, I. M. N. V, 38, t. iv, ff. 1, 2 (1900) ; Fletcher, S. Ind. Ins. pp. 285—286, f. 126 (1914).

Adoretus versutus is known from India, China, Samoa, Fiji, Chagos Islands, Mauritius, Seychelles and St. Helena.

21. Adoretus duvauceli, Bl.

Specimens of this beetle were received on 30th June 1910 from the Superintendent of the Kumaon Government Gardens at Jeolikote, who reported that they were doing a great deal of damage to the leaves of vines and figs, feeding by night.

We also have this *Adoretus* from Pusa, 7th July 1906, 18th August 1908 and 12th September 1908, and from Chapra. This is a species not unlike *A. ovalis*, but distinctly larger and much darker in colour.

Fig. 1. *Adoretus duvauceli.*

Fig. 2. *Adoretus duvauceli.*

(The small outline figure shows the natural size.)

22. Adoretus horticola, Arrow.

Specimens of *Adoretus horticola*, Arrow, were received in June 1910 and June 1912 from the Superintendent of the Government Gardens at Kumaon, where they were found attacking vine, fig, apple, pear and plum, devouring the leaves at night in association with *Adoretus versutus* and *Brahmina coriacea*.

23. Pachyrhinadoretus rugipennis, Ohaus.

Palamau, Bihar, September 1906, D. P. S. (? a pest) ; Parantij, Ahmedabad District, 21st September 1903 ; Kurnul, 1st October 1912 ; Chapra, Bihar :

We have this in some numbers from the above localities, though (curiously enough) not from Pusa.

24. Popillia histeroidea, Gyll.

Specimens collected by K. D. Shroff, Entomological Assistant, Burma, at Maymyo on 21st May 1909 were damaging leaves of *Prunus persica*.

We also have a specimen (ex Andrewes Coll.) taken at Maymyo in May 1910 and there is one in the Indian Museum from Maymyo, so that this species seems not uncommon in the Northern Shan States.

Fig. 3. *Popillia histeroidea.*
(The small outline figure shows the natural size.)

25. Popillia cupricollis, Hope.

Kumaon, United Provinces, I. R. No. 651 of 4th November 1909 from Superintendent, Government Gardens.

We also have it from Lebong (Darjiling District), September 1908 and September 1910; Turzum, Nagri Spur, Darjiling District (O. Lindgren); Simla, August 1909; Lansdowne, Garhwal, 19th October 1909; Masuri, August 1906; Gopaldhara, British Sikkim (W. K. Webb Coll.).

26. New Injurious Indian Weevils.

In Part 4 of Volume V of the "Bulletin of Entomological Research" (March 1915) Mr. G. A. K. Marshall has described and figured as novelties four Indian Curculionidæ of economic interest. These are:—

(1) *Phytoscaphus dissimilis*, found nibbling young tea shoots in Assam,

(2) *Corigetus bidentulus*, found as a serious pest of tea in Assam, occurring also in Upper Burma,

(3) *Rhynchœnus* (*Orchestes*) *mangiferæ*, described from specimens from the Godavari district in Madras. It also occurs at Coimbatore. This is the insect described and figured in *South Indian Insects* (page 334, fig. 192) under the name of the "Mango Leaf-boring Weevil,"

(4) *Pachytychius mungonis*, described from specimens from Bellary and Kurnul in the Madras Presidency. This beetle is figured and described, under the name of the "Green-gram Weevil," in *Some South Indian Insects*, pages 336-337, fig. 194.

27. Weevil Pests of Sunflower (Helianthus annuus).

A long series of upwards of two hundred specimens of *Xanthotrachelus faunus*, Oliv., in the Pusa collection has recently been identified by Mr. G. A. K. Marshall. The majority of the specimens, in cases where the foodplant was recorded, were collected on Ber (*Zizyphus jujuba*), on which this weevil is common, but numerous specimens were taken on Sunflower, which was attacked to a considerable extent when cultivated at Pusa in 1906. A few odd specimens are also labelled as found on grass and on rice.

Besides these examples from Pusa, the collection comprises specimens from Cuttack and Chapra in Bihar and Orissa, Khandala in Bombay Presidency, and from Maymyo in Upper Burma.

Besides *X. faunus*, a very similar species, *Xanthotrachelus perlatus*, Fb., was also found attacking newly-formed heads of Sunflower at Pusa in 1906. Odd specimens of this latter species are also noted as found on

Castor and on Cotton at Pusa. Except for the specimens from Pusa, the collection only contains a single example from Dehra Dun.

Both these species attacked Sunflower to a considerable extent and would probably be specific pests of this plant if cultivated on a large scale.

The following note regarding damage done to Sunflower was recorded on 25th August 1906 by Mr. C. S. Misra :—" The weevils seem to puncture the newly-formed Sunflower heads at the sides and, when a hole sufficiently wide has been made, they remain feeding on the head with their heads deeply embedded in the thick tissues of the sheathing tracts. If the beetles are in large numbers, the heads on being bored are liable to be affected by rain-water lying in the holes so made and setting up decomposition. The presence of the weevils is readily detected by their excrement which falls on the lower leaves of the plants."

28. Mango Weevils in Bengal.

A weevil was reported to be doing extensive damage to mangoes at Dacca in July 1911, but, by the time the report was received, the mango season was practically over and no beetles could be reared locally from mango fruit. Specimens of a *Cryptorhynchus*, which is presumably the guilty species, were however collected under bark of mango trees at Dacca and these have been identified by Mr. G. A. K. Marshall as *Cryptorhynchus poricollis*, Fst.

Another weevil from Dacca, collected " on mango shoot " on 19th September 1912 by P. C. Sen, Entomological Collector in Bengal, and sent in under his number E. 61, has been named by Mr. Marshall as *Alcides frenatus*, Fst. The grub is stated to bore into the shoots of grafted mango trees in the Botanical Garden at Dacca and to do considerable damage.

Fig. 4. *Alcides frenatus.*
(The small outline figure shows the natural size.)

29. A Weevil boring in dried bamboo in Ceylon.

When at Peradeniya in April 1914 I found a newly-constructed fence formed of strips of bamboo which were being extensively riddled by a weevil which was attracted to the newly-cut wood in very large numbers. This weevil has now been identified by Mr. G. A. K. Marshall as *Myocalandra exarata*, Boh.

30. Weevils in Tamarind fruits.

A weevil found breeding in some numbers in stored Tamarind fruits at Pusa in September 1908 has been identified by Mr. G. A. K. Marshall as *Calandra linearis*, Hbst.

31. Lifehistory of Batocera rubus, L.

A female specimen of *Batocera rubus*, caught at Pusa on 15th July 1914 and fed on fresh branches of Gular (*Ficus glomerata*) and Mango, lived in confinement until 13th September and deposited several eggs on and after 19th July. The first egg hatched on 30th July, the newly-hatched grub being about 7 mm. long; by 23rd August it was 25 mm. long, by 7th September about 44 mm., and by 25th September 48 mm. On 26th January 1915 only two larvæ were found alive; they were then about 62 mm. long, had ceased feeding and were apparently about to pupate; one beetle emerged on 13th May 1915, and of these one lived until 3rd August. The lifehistory, further details of which are reserved for another occasion, is thus shown to occupy one year.

32. Stromatium barbatum in Piano-wood.

In December 1914 a living specimen of a Cerambycid grub was received from a well-known Calcutta Firm with the information that these grubs were causing damage by boring in Piano-wood. The grub was reared in the Insectary and emerged on 26th June 1915 as *Stromatium barbatum*. The lifehistory of this beetle is apparently of one year's duration, the eggs being laid about June-July, the larvæ feeding up until about the next March, and the beetles emerging from May to July. The larva is commonly found boring into domestic furniture.

This case was of some interest because the Firm concerned believed that the wood, which was imported from Europe, was infested prior to importation into India. A knowledge of the exact identity of the insect concerned, however, proved that infestation took place in Calcutta.

33. Early stages of Pachnephorus impressus.

Larvæ of *Pachnephorus impressus* were found in the soil amongst roots of Maize (*Zea mays*) at Pusa on 11th August 1914. The larva

was about 4 mm. long and 0·75 mm. broad, cylindrical, tapering abruptly posteriorly, the segments distinct, very pale yellow, the head slightly darker. The thoracic legs are well developed and the first eight abdominal segments have also paired appendages (pseudopodia) on the ventral surface, each directed anteriorly and carrying several posteriorly-directed brown hairs. In life the larva remains slightly curved ventrally as shown in the figure.

Both larvæ and pupæ were found in the soil amongst maize roots. From a larva, which pupated on 14th August, the beetle emerged on 19th August 1914.

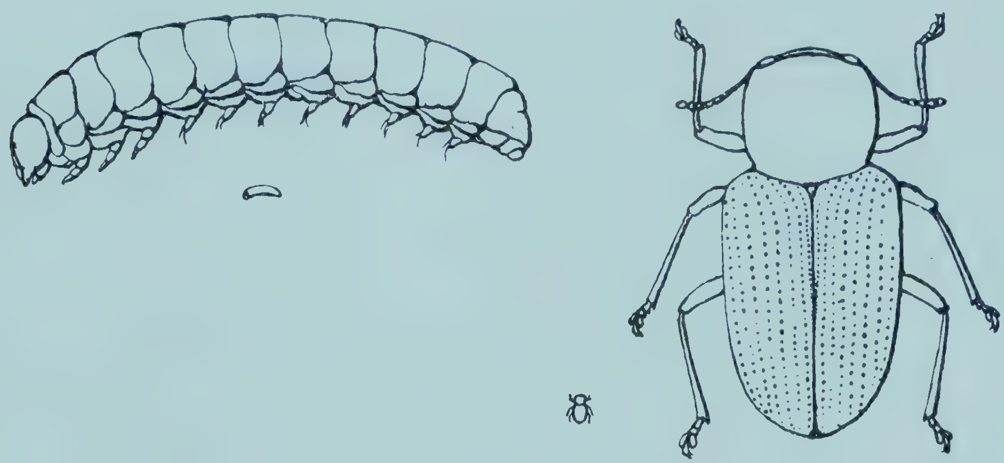

Fig. 5. *Pachnephorus impressus.*
(The small outline figures show the natural sizes.)

34. Cantharidin in Indian Blister-beetles.

In many districts in India Blister-beetles (Meloidæ) occur in very large numbers and in the adult stage are often found doing serious damage to crops although the early stages, in those species of which the early stages are known, are beneficial, as their grubs feed on eggmasses of grasshoppers. Owing to the large numbers in which the beetles occur it is feasible to collect them in some quantity and this has been done in the case of several species with a view to testing whether they are likely to be useful, especially in veterinary work, as vesicatory agents.

Two species were tested at Poona in January 1915 and the result, as communicated by Dr. H. H. Mann, gives the percentage of Cantharidin in the dried beetles as :—

Lytta tenuicollis	0·75 per cent.
Lytta picta	0·63 ,, ,,

whilst a sample of *Epicauta* sp. from the Punjab yielded 0·28 per cent. of Cantharidin on analysis by Dr. Mann.

A sample of sundried *Lytta tenuicollis* was also analysed in August 1913 at the Agricultural College at Lyallpur by Mr. J. H. Barnes, who reports the following composition :—

"Total extracted matter extractable by alcoholic hydrochloric acid and a mixture of petroleum ether and benzine . . . 23·89 per cent.

Total Cantharidin	2·17 per cent.
Free Cantharidin	1·97 " "
Combined Cantharidin	0·2 " "

"The extractable material other than Cantharidin consists of oil and fatty matters, free acetic and uric acids and phosphates of calcium and magnesium."

The difference between these two figures is considerable, due perhaps to differences in the methods of collection or preparation of the beetles, but it is clear that *Lytta tenuicollis* contains a relatively high percentage of Cantharidin, a fact which is evidenced by the effect produced by contact of the living beetle with the tender human skin.

35. Sporadic abundance of Lytta actaeon.

On 17th July 1915 a few specimens of *Lytta actæon* were brought to Pusa with the information that this Blister-beetle was present in large numbers in a field of *Setaria* on the north bank of the Chota Gandak River. On visiting the locality indicated, the beetles were found to be present in very large numbers, running rapidly over the ground or climbing up the *Setaria* plants and defoliating them. An adjacent field of *Andropogon Sorghum* was quite free from the beetles. They did not seem capable of flight but ran about with the body well raised above the ground and the abdomen slightly depressed away from the elytra so as to exhibit the reddish blotch situated on either side of the posterior end of the abdomen. The damage done was considerable as the beetles ate the leaves most voraciously and were present in large numbers, often four or five beetles on one plant. Large numbers were collected and kept in a large cage in the Insectary, but though they fed freely on *Setaria* leaves and lived for about a fortnight, no attempt at coupling was observed nor any eggs obtained ; it was noticed, however, that they were fond of hiding themselves gregariously in holes in the ground.

Usually *Lytta actæon* is rather a scarce species at Pusa but occurred in some numbers in the latter half of August 1905. Other dates for Pusa are 18th June and 10th July 1905, 10th June and 16th August 1907, 18th June 1908, 2nd July, 2nd August and 4th September 1913.

We also have it from Cuttack (on *aus* paddy, 20th July 1907); Cawnpore (22nd August 1909); Kasur, Punjab (12th July 1911); Surat (September 1903); Khandesh (T. R. Bell Coll.; no date).

36. Life history of Monomma brunneum, Thoms.

The rotten Papaya stem referred to in Note No. 1 contained a large number of grubs of this beetle. The following description of the larva was made in the Pusa Insectary: " Elongate, flattened, the sides almost parallel, slightly attenuated anteriorly. Head brown; all the other segments yellow, somewhat chitinized and shiny. Posterior segment brown with two short, brown, upturned pointed processes on each side and a flattened brown central upturned process. Three pairs of well-developed thoracic legs. The grubs are active." These larvæ were collected on 16th July and the beetles emerged on 17th and 18th August 1914.

A second lot of larvæ was found, also in a rotten Papaya stem, on 28th October 1914. The larvæ went down into the earth on 7th November. One pupated on 22nd November and attained the adult condition on 21st December, but took nearly a month to become mature, being still brown in colour on 2nd January 1915, turning darker on 9th January, and only becoming active on 18th January when it had turned completely dark-brown, almost black. It must be remembered that the weather was cold during this period. Another larva passed through the cold weather without changing, hibernating in the pupal cell.

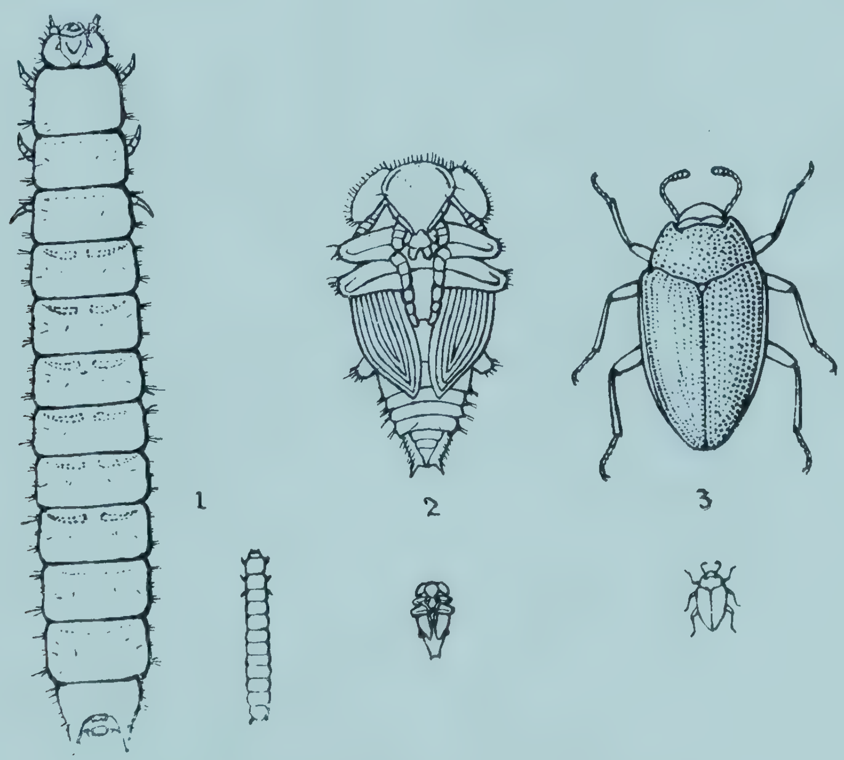

Fig. 6. *Monomma brunneum.*
(The small outline figures show the natural sizes.)

37. Some Indian Dermestid Beetles.

In the *Annals and Magazine of Natural History*, Series 8, Vol. XV, pages 425-51 (May 1915) Mr. Gilbert J. Arrow has given some "Notes on the Coleopterous family *Dermestidæ*," from which are extracted the following observations on Indian species of economic interest :—

(*a*) The generic name *Æthriostoma* is a synonym of *Attagenus*. The Dermestid common in stored wheat in the dry districts of Northern India should therefore be known as *Attagenus undulatus*, Mots. It occurs also in Ceylon, Singapore, Hongkong, the Philippines, Madagascar, Mauritius, and Australia. *Brachysphyrus irroratus*, Blackb., and *Attagenus rufipes*, Wlk., are synonyms.

(*b*) *Trogoderma versicolor*, Creutz., is recorded as having been found in rice and wheat in India. It is a common European and cosmopolitan species, identical with *T. inclusum*, Lec. We have it from Lyallpur (in stored wheat).

(*c*) *Anthrenus vorax*, Waterh., is synonymous with *A. fasciatus*, Herbst., and the name should be corrected accordingly.

(*d*) *Anthrenus subclaviger*, Reitt., originally described from Aden, is now recorded from Calcutta, the Punjab, and North-west Himalayas.

(*e*) The following Indian species are described as new :—

Attagenus birmanicus, Upper Burma ; *Orphinus jucundus*, Belgaum ; *O. nilgirensis*, Nilgiris ; *O. minor*, Belgaum ; *O. tabitha*, Ceylon (Kandy, Dikoya) ; *O. funestus*, Ceylon (Dikoya) ; *Anthrenus subsetosus*, Upper Burma ; *A. globiger*, Calcutta ; *Apsectus indicus*, Belgaum ; *Trinodes emarginatus*, Ceylon (Kandy).

38. Early stages of Thea cincta.

The Coccinellid beetle, *Thea cincta*, was reared on Red Spider (*Tetranychus*) on Jute leaves in the Pusa Insectary in October 1914 from a cluster of twenty-three eggs found on the under-surface of a Jute leaf. The egg is dull-whitish, elongate, cigar-shaped, with a smooth surface, and measures about 1 mm. in length. The grubs hatch out by bursting the free top ends longitudinally, the fissure extending downwards for about half the length of the egg.

The newly-hatched grub is about 1·5 mm. in length, flattened, the segments distinct, in colour pale yellow with a blackish spot on each side of the head and a black subdorsal spot on all the thoracic and abdominal segments except the anal segment which has a black plate.

The thoracic legs are long and well-developed and the young grub is very active.

The full-grown larva is about 9 mm. long, and similar in shape and general colour to the young grub but is tinged with yellow dorsally and has a median black marking on the head, the black thoracic spots are transversely elongated, and there is also an additional row of dorso-lateral black spots on all abdominal segments except anal.

Pupation takes place on a leaf or stem. The pupa, which is about 5 mm. long and 3 mm. broad, is pale-yellow with irregular deeper yellow dorsal patches, four black markings on posterior edge of pronotum, and the margins of wing-sheaths black, and a subdorsal black spot on first six abdominal segments.

From eggs found on 17th October were obtained larvæ which pupated on 24th October and emerged as adult beetles on 29th October 1914, so that the lifehistory is a very short one.

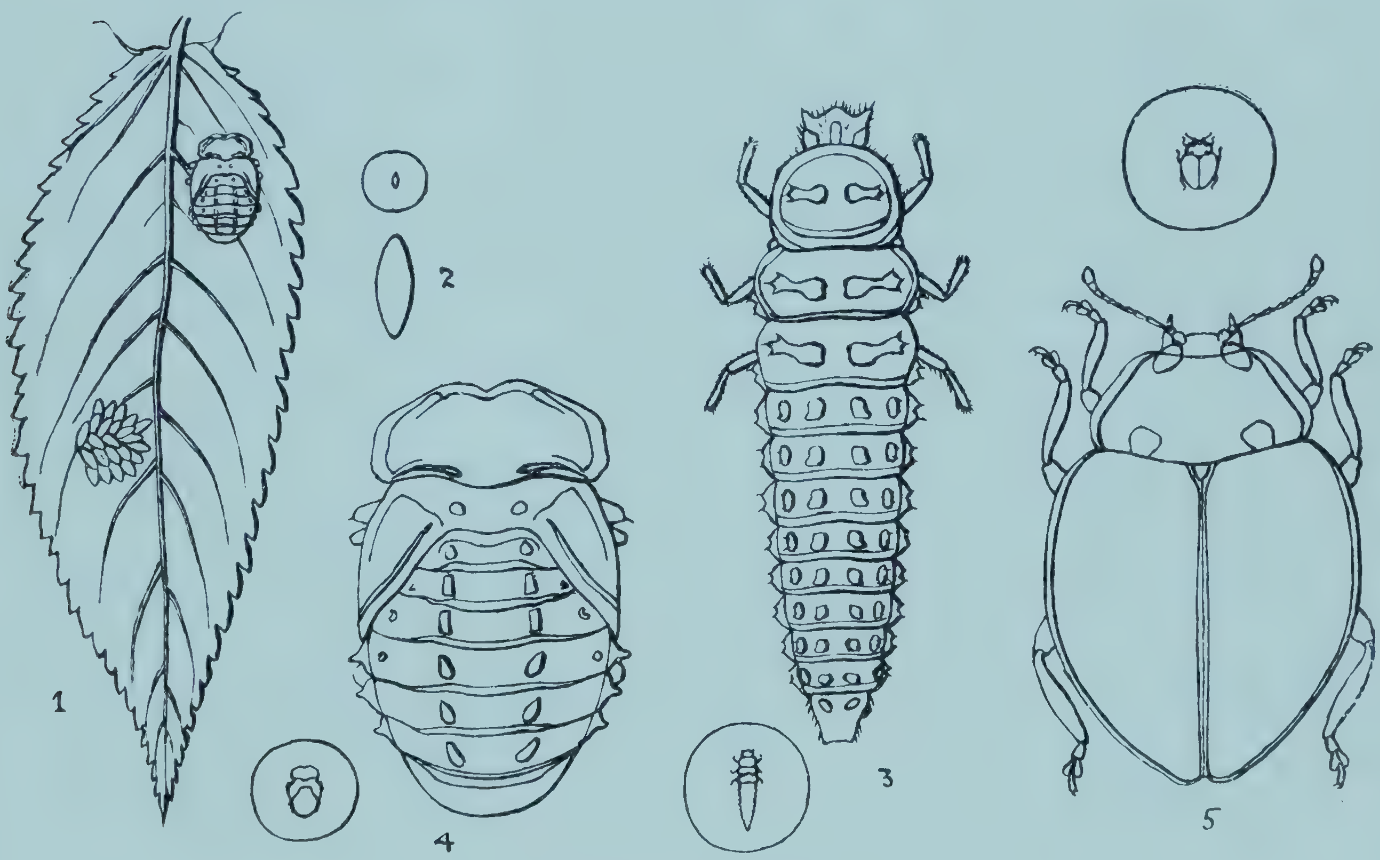

Fig. 7. *Thea cincta.*
(The small outline figures show the natural sizes.)

39. Chrysomyza aenea, Fb.

Bred (with numerous other flies) from Farmyard manure at Coimbatore, December 1913.

The species is also common at Pusa and doubtless throughout the Plains of India. We have it also from Meiktila in Upper Burma (August 1914 ; Fletcher Coll.).

40. Sepedon ferruginosus, Wied.

Common at Pusa in December-February. Also found on Paddy at Kezanathum in the Tinnevelly District (October 1913 ; Ponniah Coll.) and swept from Paddy at Chaumahani, Noakhali District, Bengal, 5th December 1911 (Fletcher Coll.). Not known to be a pest of Paddy.

Sepedon œnescens, W., is represented in the Pusa Collection by specimens from Chapra, Bihar (Mackenzie Coll.).

41. Xenaspis pictipennis, Wlk. (vespoides, Meij.)

This large fly was found commonly in North and South Coorg in May 1914. Its flight is heavy and its appearance, when on the wing, decidedly wasp-like. The flies sit on tree-trunks and on leaves, frequently on leaves of Pepper Vines growing up the trees. When caught, the fly extends its mouthparts and exudes therefrom a large drop of opaque brownish liquid which it deliberately attempts to smear upon its captor. I was informed by a local Coffee Planter that he had seen these flies feeding upon cowdung but the numerous specimens which came under my own observation were not observed to do this.

42. Oxyna parca, Bezzi. (Mem. Ind. Mus. III. 159-160, t. 10, f. 62.)

This species was described from a single pair taken at Calcutta in September and October 1907. We have a specimen from Tranquebar 6th to 9th May 1915, so that this species is probably widely distributed in the Plains. Nothing is known of its lifehistory.

43. Campiglossa cribellata, Bezzi. (Mem. Ind. Mus. III. 161, t. 10, fig. 63.)

Described from a single specimen from Kurseong. The Pusa collection also contains a single specimen taken at Pusa on 19th March 1914.

44. Tephritis zodiacalis, Bezzi. (Mem. Ind. Mus. III. 163-164, t. 10, f. 65.)

A single specimen from Pusa on 4th January 1915. Apparently not a common species as it was described from a single specimen from Calcutta in the Indian Museum collection.

45. Tephritis zonogastra, Bezzi. (Mem. Ind. Mus. III. 164, t. 10, fig. 66.)

This species was described from a single specimen in the Indian Museum collection taken at Puri in December 1908. It is therefore interesting to note that this species is also included in a small collection of insects made in May 1915 at Dungagali, at an elevation of over 8,000 feet in the Hazara District.

46. Tinda indica, Wlk.

Bred at Pusa, August 1913, from larvæ found in a Plantain stem. Also from Chapra, Bihar (Mackenzie Coll.).

47. Argyramoeba ceylonica, Brun.

Bred at Pusa as a parasite of *Pseudagenia clypeata* (18th March 1909 ; G. R. Dutt). This is the species referred to as *Hyperalonia* sp. in *Entom. Mem. IV,* pages 195-196, and the necessary correction therein may be made accordingly.

48. Systoechus socius, Wlk.

Bred from larvæ predaceous on eggs of *Colemania sphenarioides* at Hadagalli, Bellary District, in October 1911 (Y. Ramachandra Rao coll.; No. 409). A very distinct-looking species with strong yellowish pubescence. In another specimen from Coimbatore (30th May 1912) the colour is pale yellowish-grey.

This is the species referred to in *South Indian Insects* (page 204).

49. Paragus serratus, Fb.

Predaceous on Green Aphid on *Phyllanthus emblica,* Pusa, 27th July 1914. (C. No. 1072).

We also have it from Samalkota, where it was found predaceous on Aphid on shoots of *Cajanus indicus,* 23rd November 1906 (Y. Ramachandra Rao) and from Coimbatore (19th September 1913 ; Fletcher Coll.) where this fly was found in a Ragi field and is almost certainly the Syrphid predaceous on the Ragi Root Aphis (see *South Indian Insects,* page 198).

50. Sphaerophoria scutellata, Fb.

Bred from larva predaceous on Aphids on garden Crysanthemum, Pusa, 1st February 1915 (Fletcher Coll.), and from larva feeding on Watermelon Aphis at Hagari, Bellary District, 11th May 1907 (Y. Ramachandra Rao Coll.; No. 109). We also have this species from the Anamalai Hills

(Kalyana Pandal; 3,000 feet, 25th January 1912; Fletcher Coll.), from Coimbatore (on cotton; 8th June 1912; Fletcher Coll.), and from Assam.

This is the species shown on the coloured plate of a Syrphid Fly in *Indian Insect Life* (Plate LXIV) and in *South Indian Insects* (Plate XV).

51. Atherix cincta, Brunetti.

A single specimen from Maymyo (Upper Burma; 3,500 feet) in August 1914 (Fletcher Coll.).

52. Macrocera flavicosta, Brunetti. (Faun. Ind. Dipt. Nemat., page 53. t. i. f. 3.

A single specimen from Ootacamund (7,500 feet) in December 1913 (Fletcher Coll). This species was described from a specimen " without exact data, but certainly captured in the East, most probably in India," so that the present record presents the first exact locality.

53. Sciara rufithorax, Wulp. (Brunetti, Faun. Ind. Nemat., pages 128-129, t. iii. f. 15.)

Bred at Pusa on 24th August 1914 from a mass of larvæ found underground. More than a hundred larvæ were found intertwined into a large lump, all of them continually moving but never separating from the mass. If one moved in any direction, others would follow so that a protrusion occurred from the main body which might be elongated in following these leaders; but those in the rear soon closed up so that the whole formed one mass as before.

These larvæ were found on 19th August and were evidently full-grown, as a few pupated next day and almost all the rest on 21st August. In pupating they spread out over the surface of the earth and were found to have spun a little silk (? dried mucus) which webbed together a few pellets of earth, but no regular cocoon was formed.

Eighty-five flies emerged on 24th August and there were also twenty-four other individuals which either died or were preserved in the earlier stages.

54. Pselliophora laeta, Fb. (Brunetti, F. I. Dipt. Nemat., pages 291-292, t. v. f. 2, t. vi. f. 9.)

Two specimens from Santikoppa, North Coorg, in May 1914 (Fletcher Coll.). The species is apparently widely distributed in the Hills in

Southern India. We also have it from Hillgrove, in the Nilgiris (4,000 feet), 27th April 1915.

55. Pselliophora taprobanes, Wlk. (Brunetti, F. I: Dipt. Nemat., pages 293-294, t. v. f. 3, t. vi. ff. 10, 11.)

A male from Yercaud (4,500 feet) in the Shevaroy Hills in December 1913 (Fletcher Coll.). This species seems to have been recorded only from Ceylon hitherto.

56. Tipula melanomera, Wlk. (Brunetti, F. I. Dipt. Nemat., page 330.)

Two specimens from Maymyo in Upper Burma (August 1914; Fletcher coll.) appear to belong to this species which was originally recorded from Nepal. It is apparently not a common insect, as it was not represented in the Indian Museum collection where one of these specimens has now been deposited.

57. Teucholabis fenestrata, O. S. (Brunetti, F. I. Dipt. Nemat., page 429, t. viii. f. 14, t. xi. f. 10.)

One specimen from Maymyo (3,500 feet) in Upper Burma, August 1914 (Fletcher coll.). This species has been recorded from Ceylon and North-East India but does not seem to have been noted definitely from Burma.

58. Gymnastes cyanea, Edw. (Brunetti, F. I. Dipt. Nemat., pages 431-432.

Gymnastes violaceus. Brunetti, Rec. Ind. Mus. VI. 282, F. I. Dipt. Nemat., pages 433-434, fig. 42, t. viii f. 10.)

A single specimen from Sidapur, Coorg, in November 1912 (Fletcher coll.). In life it mimicks a Reduviid bug. This species has hitherto been recorded only from Ceylon.

59. Conosia irrorata, Wied. (Brunetti, F. I. Dipt. Nemat., pages 497-499, fig. 43.)

We have this from Pusa, Peshawar, Hopin in Upper Burma (30th August 1914; Fletcher coll.) and from Thaton and Rangoon in Lower Burma (September 1914; Fletcher coll.). It frequently occurs in large numbers in Paddy fields, being attracted to light at night, and must be looked on with suspicion as a probable minor pest of Paddy.

60. Rhyphus distinctus, Brunetti. (Rec. Ind. Mus. IV. 262, F. I. Dipt. Nemat., pages 556-557, t. xii. f. 6.)

A single specimen from Ootacamund (7,500 feet) in December 1913 (Fletcher coll.). This species is only recorded hitherto from the Darjiling District and from Assam.

61. Euchromia polymena as a pest.

The larvæ of *Euchromia polymena*, L., have been reported by R. M. Pillai as an occasional minor pest of Sweet Potato in Travancore, destroying the leaves. As a rule the larvæ feed on wild Convolvulaceæ.

62. Sesamia inferens and S. uniformis.

The references to these two species in Indian Economic Entomology have led to considerable confusion and it may be useful to indicate the differences. In *Sesamia inferens*, Wlk., the antennæ of the male moth are bipectinate with extremely short branches, the apex serrate; in *S. uniformis*, Ddgn., the cilia of the male antennæ are fasciculate.

Examination of the series in the Pusa Collection indicates that *S. inferens* is the commoner of the two and we have this from Pusa (rice-stubbles, rice-stem, Guinea-grass stem and sugarcane), Bankipur (rice-stem), Nagpur (wheat-stem, juar-stem and maize), Seoni (wheat), Coimbatore (ragi, Sorghum-stem and tenai (*Setaria*), Hagari (rice-stem), Surat (maize, wheat-stem, juar-stem) and Navsari (maize).

Sesamia uniformis we have only from Lyallpur (sugarcane and maize) and Pusa (a single specimen reared from a maize-stem).

Further long series of these insects from all localities are required to ascertain their distribution and foodplants.

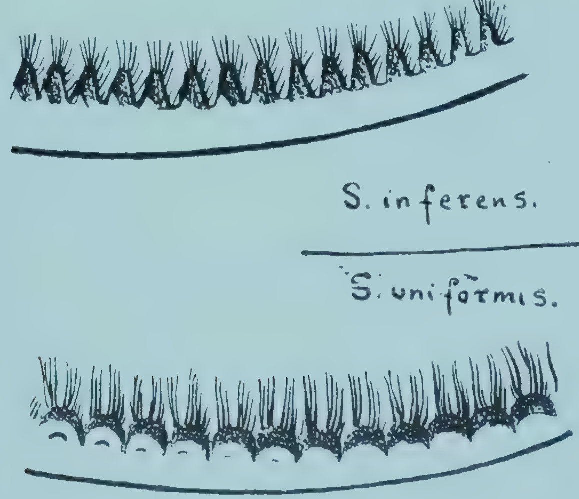

Fig. 8. *Sesamia inferens* and *S. uniformis*, portions of male antennæ.

63. Synonymy of " Ophiusa melicerta. "

In the *Review of Applied Entomology*, Series A, Vol. III, p. 145 (March 1915), this species is referred to as *Achœa janata*, Linn., and reference to the original authority shows that the description is applicable. The synonymy will therefore be :—

Geometra janata, Linn., Syst. Nat. (ed. X), p. 527 (1758), l. c. (ed. XIII) p. 2479.

Phalœna janata, Fab., Sp. Ins. II, 263 (1781), Mant. II. 206 (1787), Ent. Syst. III. ii. 190 (1794).

Noctua melicerta, Drury, Ill. Exot. Ins. I. 42, t. 23 f. 1. (1770).

Ophiusa melicerta, Hmpsn., Faun. Ind. Moths, II. 494-495, etc.

As regards the generic name *Achœa*, see Sir George Hampson (*Catalogue of the Lepidoptera Phalœnœ*, Vol. XII, page 496).

64. Fruit-destroying Moths.

In July 1914 the Superintendent of the Kumaun Government Gardens forwarded for identification some specimens of moths which were stated to " do an enormous amount of damage to fruit crops, particularly peaches and nectarines. They commence their ravages at about 9 P.M., puncturing all the fruits on which they alight....... They are most destructive and will most certainly ruin the peach industry as far as this elevation is concerned."

The moths proved to be nearly all specimens of *Calpe ophideroides*, which was not previously represented in the Pusa Collection. The sending included also one specimen each of *Ophiusa honesta* and *Achœa janata* (*Ophiusa melicerta*), both of which were probably merely accidental visitors attracted to fruit which was rotting or already damaged by *Calpe ophideroides*. On examination of the tongue of this last named species, it will be seen that the tip of the tongue (as shown in the figure) is armed with a formidable array of spines which are quite capable of cutting through the skin of a peach.

Another common Indian moth whose tongue is similarly armed is *Ophideres fullonica* which has acquired a sinister reputation in South Africa and Queensland on account of its habit of puncturing orange fruits in a similar way. This species is recorded (*Indian Museum Notes*, Vol. V, page 118) as attacking pomelo fruits at Tardeo, Bombay, causing a loss of a quarter to a third of the crop, the attacked fruits falling from the trees.

As regards control measures, it might be possible to trap the moths in pans or bottles containing water with a little ripe fruit and jaggery

or to poison them directly by means of baits, of jaggery mixed with Lead Arsenate, suspended in or near the trees attacked.

Fig. 9. *Calpe ophideroides,*

Fig. 10. *Calpe ophideroides,* tongue, greatly magnified.

Fig. 11. *Ophideres fullonica.*

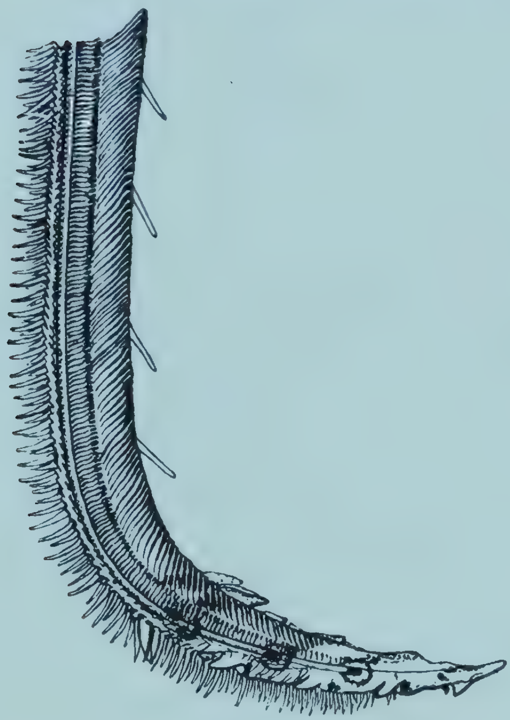

Fig. 12. *Ophideres fullonica*, tip of tongue, greatly magnified.

65. Early stages of Leucophlebia lineata.

A female of *Leucophlebia lineata*, caught at light at Pusa on the evening of 6th July 1915, was confined on a small sugarcane plant and deposited 207 eggs by 10th July, when it died. The eggs, which were laid at night, were scattered over the cane leaves and the inside of the cage, each attached separately. The pearly egg is small for the size of the moth, about 2 mm. by 1·5 mm., the surface smooth and shiny and greenish-yellow in colour. The first eggs, which were laid on the night of 7th July, hatched on the morning of 12th July, the larvæ devouring the empty eggshells before wandering in search of food. Leaves of maize and sugarcane were offered, but only the cane-leaves were

eaten. The first larva went into the earth about a month, and the last about seven weeks, after hatching, the moths emerging from 24th August onwards.

The general appearance of the larvæ is shown in the figures, where (1) represents a larva at the end of the antepenultimate moult and (2) a larva in its last instar. The difference in the shape of the head, in the younger and later stages, is very noticeable. The general colour of the fullgrown caterpillar is bright pale green with a whitish subdorsal stripe, and the sides of head, legs, and tail rosy pink. The larva rests head-downwards on the edge of the leaf, eating inwards from the margin. The pupa is dark reddish-brown. A fuller description of the early stages is reserved for another occasion.

Leucophlebia lineata has not been noted as a pest of sugarcane in India but occasionally appears in small numbers and may perhaps at times become a minor pest. It is known to feed on sugarcane in Formosa and Java.

Fig. 13. *Leucophlebia lineata.*

66. Gynandromorphism in a Lasiocampid Moth.

The figure represents a noteworthy gynandrous example of *Metanastria hyrtaca* reared by R. M. Pillai on 27th July 1914 from a larva found at Trivandrum, Travancore State, on the bark of a tree of *Eugenia jambolana.* As will be seen, the wings and antenna on the right-hand side are male, those on the left-hand side female, the difference being accentuated by the different size, shape and markings of the wings in the two sexes. The genitalia have not been dissected out but the general shape of the body resembles that of a male although, as will be seen by inspection of the lower figure which shows the posterior portion of the abdomen as seen from beneath, the apex of the abdomen is strongly asymmetrical and the accessory sexual characters apparently partake of those of both sexes, male on the right-hand side and female on the left as in the case of wings and antennæ.

Fig. 14. *Metanastria hyrtaca.*

67. Catopsilia eaten by Drongo.

On 15th April 1912, at Pusa, I saw a *Catopsilia* fly out of a Litchi-tree whereupon it was pursued by a Drongo (*Dicrurus ater*). The butter-

fly doubled and twisted and a second Drongo joined in the chase, but the first bird caught the butterfly after at least half-a-dozen attempts, flew away with it on to a branch, and ate it. Apparently wings and all were eaten, as I watched but did not see anything drop. This took place at about 7 A.M.; it was a dull and (for the time of year) cold morning. Probably the bird was hungry as few insects were astir owing to wind and absence of sun. The butterfly was probably *Catopsilia crocale.*

Exact records of the attacks of birds on butterflies are much wanted in India. There is no doubt that birds do eat butterflies and this probably occurs much more commonly than is generally supposed, but it is usually impossible to identify the species concerned, as the birds are acutely conscious of observation. During the Christmas holidays of 1913, when at Ootacamund, I saw four cases of birds attacking and capturing butterflies, but in no case was it possible to be certain of the species.

68. Aberration of Pieris brassicae, L.

The figure shows an unusual aberration of *Pieris brassicæ*, L., reared at Pusa on 10th March 1915 from a larva found feeding on Nasturtium (*Tropæolum*). The usual black markings of the forewings are much extended, the base of wings and costal area being heavily irrorated with black scales, the upper black spot prolonged into the terminal black margin which is continued to the tornal angle where it joins the elongated black streak on inner margin, whilst the lower black spot (below vein 2) is prolonged outwards and connected to the terminal border and the upper spot by distinct black irroration. On the hindwing there is some black irroration towards termination of veins 5, 6 and 7. On the under-surface of forewing the two black spots are connected by black irroration.

The other individuals (four males and two females), bred from this batch of larvæ, were quite normal.

Fig. 15. Aberration of *Pieris brassicæ.*

69. Synonymy of " Scirpophaga auriflua."

In the " Fauna of India " (Moths, Vol. IV, p. 46), Sir George Hampson quotes the names given to this insect by Walker and Zeller, giving the former precedence. But Meyrick had already shown (*Ent. Mo. Mag.* 1890, 111) that part XXVII of Walker's Catalogue was published on 18th April 1863, Zeller's Monograph Chil. and Cramb. not until July 1863. Walker's name has therefore precedence and this insect must be known as *Scirpophaga xanthogastrella*, Wlk. (*auriflua*, Z.).

70. Synonymy of " Polyocha saccharella."

Sir George Hampson has shown (*Bombay Journ.* XXI, 1251) that this insect, described by Dudgeon from specimens bred from sugarcane at Durogah in Bihar, is identical with No. 4312 of the " Fauna of India " List of Moths, *Polyocha depressella*, Swinh., and differs in neurational structure from *Polyocha.*

In the *Review of Applied Entomology*, Series A, Vol. III, p. 145, this moth is referred to as *Papua depressella*, Swinh., and this name may therefore be used. The genus *Papua* was established in 1889 by Ragonot (*Bull. Soc. Ent. France* (6) IX, p. ccxx) for *latilimbella*, Rag., from New Guinea.

71. Leucinodes orbonalis boring Potato plants.

Specimens of *Leucinodes orbonalis*, Gn., were reared at Poona in August 1913 from larvæ boring topshoots of Potato. This moth is a well-known pest of Brinjal (*Solanum melongena*) boring in the shoots and fruits, and has also been bred from *Solanum xanthocarpum*, but its occurrence in Potato (*Solanum tuberosum*) is quite exceptional.

72. Synonymy of " Pachyzancla aegrotalis."

The name *bipunctalis*, Fab. (Ent. Syst. III, ii. 227) has precedence over *ægrotalis*, Zell., and should be used.

73. A new Synonym of Platyptilia pusillidactyla, Wlk.

Mr. Busck has recently redescribed specimens of *Platyptilia pusillidactyla*, Wlk., from Hawaii under the name *Platyptilia lantana* (*Insec. Inscit. Menstr.* II. 103-104 ; July 1914). Specimens received from Mr. Swezey, of Honolulu, leave no doubt regarding the identity, and the name *lantana*, Busck, must therefore sink as a synonym.

This moth is common throughout India, Burma and Ceylon and is referred to and figured in *South Indian Insects*, page 444.

74. Meridarchis scyrodes in Ber Fruits.

Meridarchis scyrodes, Meyr. MS., was reared at Coimbatore in February 1913 from larvæ found boring into fruits of Ber (*Zizyphus jujuba*), and was also bred from Ber fruit at Pusa in March and April 1915.

75. Larva of Argyroploce erotias, Meyr.

This Eucosmid moth has been reared at Pusa from larvæ found feeding on tender Mango leaves in March 1912. The larva is about 16 mm. long by 2 mm. broad, slightly flattened and tapering towards the extremities, in colour uniform green, the skin soft and segments distinct ; head flattened, greyish yellow, smaller than prothorax which is entirely covered by a shield darker than the head ; all legs present and equally developed. The larva rolls up the tender leaves of young Mango-shoots by means of white silk threads, living in hiding and biting holes in the rolled leaves. When full-fed, it pupates in a cocoon formed of rolled leaf lined with white silk ; the pupa is protruded to some extent before emergence of the moth. We also have specimens reared in October 1905 from larvæ boring mango shoots in Bombay.

76. A new pest of Arhar.

Moths reared from pods of Arhar (Tur, Red Gram ; *Cajanus indicus*) at Pusa in April and May 1914 have been determined by Mr. Meyrick as *Laspeyresia trichocrossa*, Meyr. MS.

The larvæ were found in March, boring the pods and eating the seeds. As a rule the larva pupates inside the pod, having first prepared a hole of exit for the moth, this hole being covered with silk and frass. The pupa wriggles out through this hole and protrudes for half its length outside the pod before the moth bursts out of the pupal case. In some cases, the larva may pupate outside of the pod in a cocoon formed by rolling up a few dry petals. After forming the pupal chamber the larva seems to remain in a resting state for some three weeks before pupating, the moth emerging after another three or four weeks.

77. New Foodplant of Phthorimaea operculella.

Specimens of pupæ received from Dharwar Farm on 21st November 1912 as reared from larvæ mining leaves of Brinjal (*Solanum melongena*) produced moths which have been identified as *Phthorimæa operculella*, Z., and this identification has been confirmed by Mr. Meyrick. So far as is known, this is quite a new foodplant in India for this destructive pest which has hitherto confined its attentions to potato. In America

and South Africa it is of course well known as a destructive miner in tobacco leaves but has not been noted to attack tobacco in India.

78. Anarsia melanoplecta boring Mango-shoots.

The Gelechiad moth *Anarsia melanoplecta*, Meyr., was reared at Pusa in March 1912 from a larva found boring the top-shoot of a young mango twig, and covering the affected part with black pellets of frass held in place on a webbing of white silk. The larva is about 8 mm. long by 1 mm. in breadth, cylindrical, the segments well defined, in colour yellow with a pinkish tinge, the anal segment darker. The head and prothorax slightly smaller than the metathorax which is the broadest part of the body. The head is shining black, the prothorax dark-grey with a prominent black shiny shield divided medially by a fine line. Five pairs of equally developed prolegs are present.

In confinement the larva pupated in a cocoon spun amongst small twigs on the bottom of the cage, the moth emerging a fortnight later.

79. Gelechiad Pests of Stored Rice.

The small moths commonly found in stored rice are usually lumped together under the name *Sitotroga cerealella*, Oliv., but it may be useful to draw attention to the fact that *Epithectis studiosa*, Meyr., and *Aristotelia austeropa*, Meyr., have also been reared from stored rice in India. All are very similar in general appearance and colour and are best distinguished by the structural differences characteristic of the different genera ; in this way they may easily be separated by the following artificial key :—

1	Hindwing veins 3 and 4 connate . .	*Epithectis.*
	Hindwing, veins 3 and 4 remote . .	2
2	Hindwing, veins 6 and 7 stalked . .	*Sitotroga.*
	Hindwing, veins 6 and 7 parallel .	*Aristotelia.*

80. Epithectis oschophora, Meyr., was reared at Coimbatore in 1914 from Cholam stubble. The species is probably a rubbish-feeder and not a pest of Cholam.

81. Generic Name of " Gnorimoschema heliopa."

This little moth, which has been placed in the genus *Gnorimoschema* in *Indian Insect Life* and *South Indian Insects*, is really a *Phthorimæa* and should be removed to that genus.

82. Chelaria spathota, Meyr., was reared at Pusa in December 1909 from a larva found eating Mango leaves. It has also been reared from a larva found on tender Mango leaves at Koilpatti, Madras Presidency, in November 1909. It is apparently not a very common insect, however.

83. Another new minor pest of Indigo.

Anataractis plumigera, Meyr. MS., reared from pupa in stem of Indigo at Pusa, 4, May 1912, C. No. 945. The stem was swollen into a gall and evidently the larva had fed inside the stem.

84. Mango Leaf-miners.

Several small moths mine leaves of Mango. Amongst those reared at Pusa from such leaf-miners are various species of *Acrocercops*.

Acrocercops syngramma, Meyr., was reared at Pusa in September 1907 and again in August 1908 from larvæ mining leaves of Mango. A specimen of the moth was also taken at Bankipur in October 1911.

Acrocercops cathedræa, Meyr., was reared from a Mango leaf-miner at Pusa in August 1908 and also from leaves of Chichri (*Achyranthes aspera*) at Pusa in September 1906. I also took a specimen at Rajshahi in Eastern Bengal in March 1911, and have it also from Coimbatore (at light, 31st May 1913). It may be noted here that *A. cathedræa* is the species referred to in *Indian Insect Life* (page 538) as *A. phalarotis*, an unpublished manuscript name.

Acrocercops isonoma, Meyr. MS., a single specimen reared from Mango in May 1907.

85. Camphor Leaf-miner.

In December 1909 Mr. R. D. Anstead, the Planting Expert in Southern India, forwarded two small moths reared from larvæ mining in leaves of Camphor leaves on Chundrapore Estate, Mudigere, Kadur District, Mysore State, and wrote :—" In October last some Camphor leaves were sent to me attacked by a small mining caterpillar. The caterpillar was feeding in the palisade parenchyma of the leaf leaving the epidermis, which dried into a blister-like shelter over it. Patches were thus made on the leaf about $\frac{3}{4}$ inch by $\frac{1}{2}$ inch." These moths have been identified by me as *Acrocercops ordinatella*, Meyr., originally described from New South Wales and subsequently from Queensland and Ceylon. In Ceylon it was bred from a larva mining leaves of *Litsea* at Peradeniya. It is probably the " Leaf-miner of Camphor " referred to by Rutherford (*Trop. Agric.*, June 1914), whose brief description seems to fit the moth sufficiently well.

References to literature :—

Gracilaria ordinatella, Meyr., Proc. Linn. Soc. N. S. W., V. 145 (1880)(1).

Conopomorpha ordinatella, Meyr., l. c. XXXII. 54 (1907)(2).

Acrocercops ordinatella, Meyr., Bombay Journal, XVIII., 816 (1908) (3) ; *id.*, Wytsm. Gen. Ins. fasc. 128, p. 15 (1912)(4); *id.*, Exot. Micr. I. 285 (1914) (5).

Acrocercops sp., Rutherf., Trop. Agric. (June 1914) (6) ; *id.*, Bull 15, Ceylon Dept. Agric. p. 7 (1914) (7).

New South Wales (1, 2, 4), Queensland (2, 4), Ceylon (3, 4, 5, 6), Burma (7).

86. A Litchi Leaf-miner.

Acrocercops hierocosma, Meyr., was bred in September 1907 from larvæ mining leaves of *Nephelium litchi* at Pusa.

87. Foodplants of Acrocercops telestis, Meyr.

Specimens of *Acrocercops telestis*, Meyr., were reared at Coimbatore in February 1913 from larvæ on *Trewia*. It has also been reared at Pusa in August 1907 from *Gmelina arborea* and in September 1913 from leaves of Jamun (*Eugenia jambolana*). Lefroy in *Indian Insect Life* (p. 538) records this species as mining leaves of *Trewia nudiflora* in Bihar

88. A new minor pest of Red Gram in Madras.

Moths bred from larvæ rolling leaves of Red Gram (*Cajanus indicus*) at Coimbatore in November 1913 have been identified by Mr. Meyrick as *Gracillaria soyella*, van Dev., originally described from larvæ in leaves of *Soya hispida* in Java, and later recorded from Colombo and Hakgala in Ceylon, as reared from larvæ mining leaves of *Cajanus indicus* and drawing together terminal leaves of *Atylosia candollei*. All these plants are Leguminosæ and this little moth is probably more widely distributed in India. We have also reared it from *Cajanus indicus* at Pusa in February and March. References to literature are :—

Gracilaria soyella, van Deventer, Tijds. v. Ent. XLVII. 22-25, t. ii., ff 1, 1a (1904) ; Meyr., Wytsm. Gen. Ins. pt. 128, p. 30 (1912).

Gracilaria acrotherma, Meyr., B. J. XVIII. 830 (1908).

89. Prays citri, Milliere.

This little moth, originally described from Southern Europe, is now known to occur in New South Wales and in the Philippines and has recently been recorded from India (North Coorg) and Ceylon (Colombo, Maskeliya and Madulsima). In Southern Europe it is well known as an injurious pest of the orange and other species of *Citrus*, the larva eating into all the flower organs and boring in the shoots, whilst in the Philippines the larva has been found to bore into the rind of Citrus fruits, making a gall so that considerable damage to the fruit may be caused. In India and Ceylon this moth has not yet been noted as doing any damage but it is quite likely to do so and attention is therefore called to its occurrence within our area.

Fig. 16. *Prays citri.*
(The small outline figure shows the natural size.)

90. Acrolepia manganeutis, Meyr., on Stored Yam.

A series of *Acrolepia manganeutis*, Meyr., in the Indian Museum collection, was reared from larvæ and pupæ found on stored yams in Tollyganj, Calcutta, on 1st December 1911. The moths emerged between 21st December 1911 and 6th January 1912, pupation being effected within a curious net-work cocoon recalling that made by *Plutella maculipennis*. We have it also from Ootacamund (in December).

Further details regarding the occurrence of this moth are at present *desiderata*, but as it is recorded from Ceylon (Maskeliya) and the Khasi Hills it may perhaps prove of some economic interest in districts where yams are grown.

The moth is described by Mr. Meyrick in *Exotic Microlepidoptera*, Vol. I, p. 149 (December 1913).

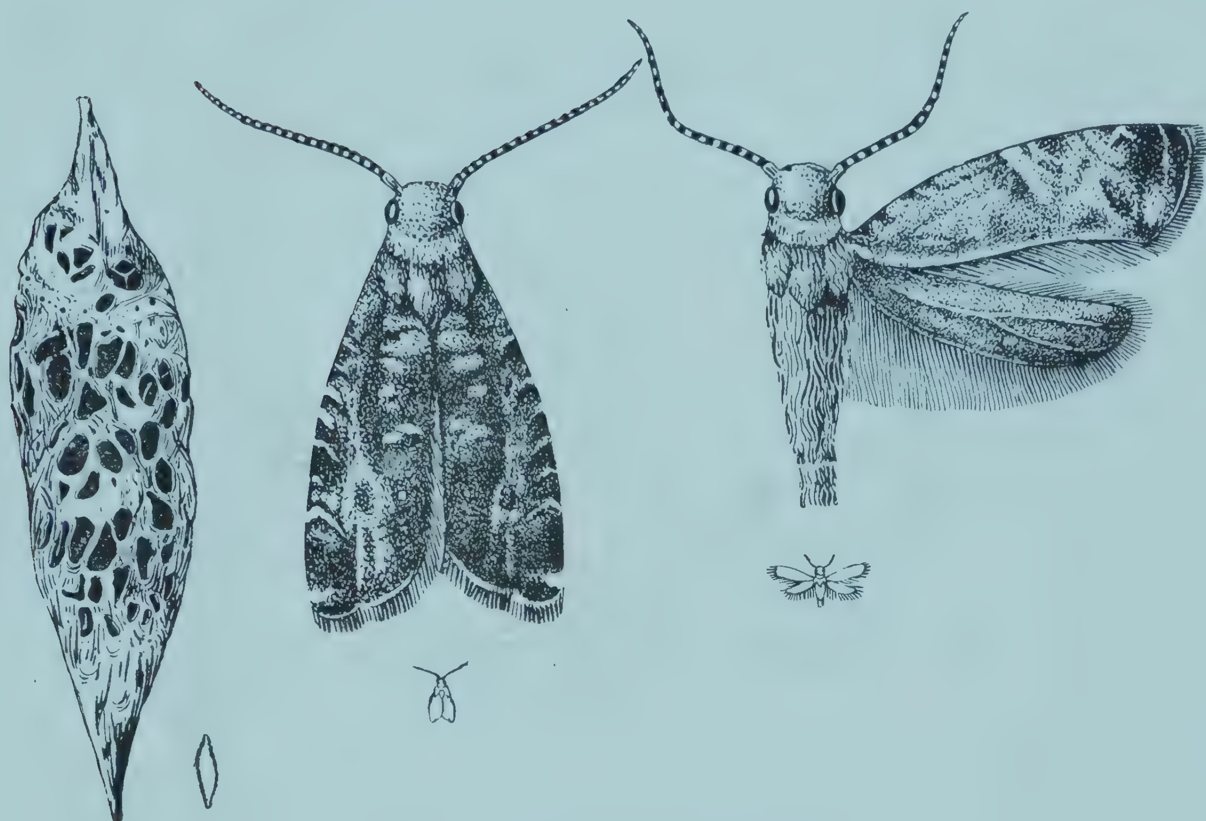

Fig. 17. *Acrolepia manganeutis.*
(The small outline figures show the natural sizes.)

91. A new minor pest of Indigo.

A small moth reared from larvæ on Indigo top-shoots at Gorakhpur and Dalsing Serai in September 1912 has been determined by Mr. Meyrick as *Petasobathra sirina*, Meyr. (Lyonetiadæ).

The larva is about 4·5 mm. long and about 0·75 mm. across the middle of the body which tapers towards each extremity ; the segments are distinctly separated by deep constrictions ; shape flattened ; head

flat, yellow, somewhat elongate, smaller than prothorax ; colour uniform dirty white ; thoracic legs and five pairs of prolegs greyish.

The larva covers the top-shoots with a profuse web of fine white silk under cover of which it lives and nibbles small portions of the leaf-surface. It is often seen to walk over the webbing. When full-fed it spins a pure-white somewhat elongated cocoon in any suitable situation which provides some corner, *e.g.*, along the midrib on the upper surface of a leaf or in a rolled or folded leaflet. The moth emerges after about a week and rests with the anterior half of the body well raised and the antennæ held extended at right angles to the body.

92. The Indian " Clothes-moth."

The common black-and-white Indian " Clothes-moth," hitherto recorded in *Indian Museum Notes, Indian Insect Life*, and *South Indian Insects* under the name *Trichophaga tapetzella* is really *Trichophaga abruptella*, Wll. (= *bipartella*, Rag.) which replaces *T. tapetzella* in hot countries. The true *T. tapetzella* is not known to occur in India and the necessary corrections should be made.

93. Appearance of Croce filipennis on the wing.

The date of appearance on the wing of *Croce filipennis* seems to be very regular. In 1910 this insect was noticed commonly at Pusa in the second week of April. In 1911 the first specimen was noted on 6th April, it was very common about 8th-15th April, then gradually decreased in numbers until the last survivor was seen about 8th May. In 1912 the earliest example was seen in the Laboratory on 1st April ; this must have been a precocious individual as no more were seen until 5th April, when they were common in bungalows and by 19th April, when I left Pusa, they were beginning to get scarce again and many dead individuals were seen lying about on windows, etc. In 1913 and 1914 I was away from Pusa in April, but in 1915 the first one was seen on 6th April in the Laboratory ; they were common about 20th April, occurring in little groups and pairing was doubtless taking place at this time although not actually noted ; a solitary straggler was seen on 25th April but by 27th April none could be found.

Although this insect is sufficiently common at Pusa there seems to be remarkably little information available regarding its occurrence elsewhere. It was described from Central India and occurs at Calcutta, appearing there a week or two earlier than at Pusa.

94. Rhynchocoris humeralis, Thunbg. (Distant, Faun. Ind. Rhyn. I. 212-213, f. 133.)

Found in some numbers on orange at Myitkyina, Upper Burma, in August 1914. The insects were present in numbers sufficient to constitute a minor pest.

This species is described in the " Fauna " volume as ochraceous or greenish-ochraceous and old preserved specimens are of this colour, but in life the colour is a rich dark leaf-green, exactly the tint of the orange leaves.

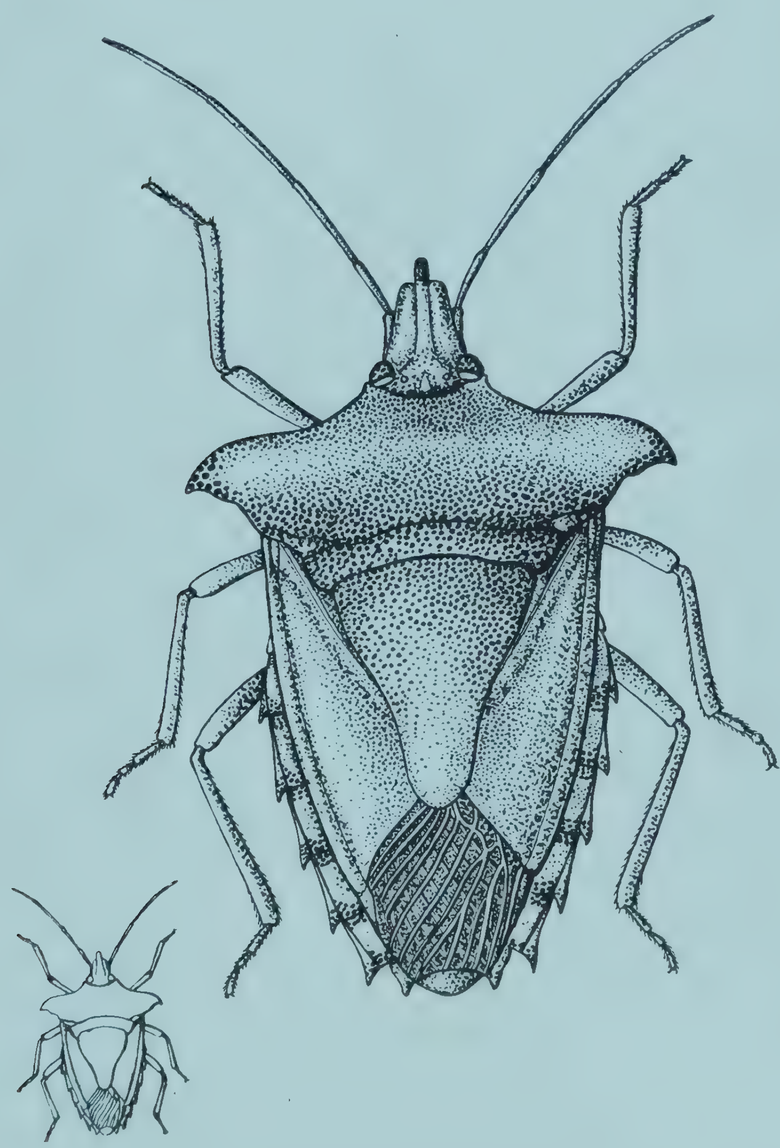

Fig. 18. *Rhynchocoris humeralis.*
(The small outline figure shows the natural size.)

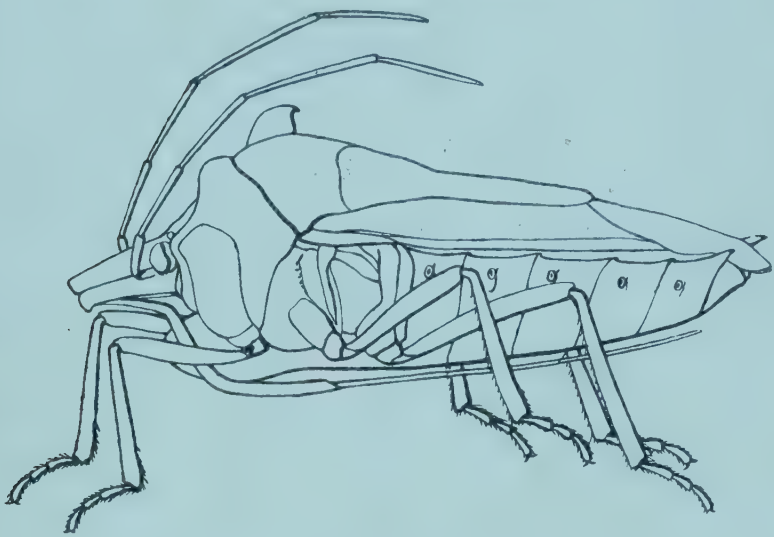

Fig. 19. *Rhynchocoris humeralis.*

95. Rhynchocoris plagiatus, Wlk. (Distant, Faun. Ind. Rhyn. I. 213.)

Found in considerable numbers on Coca (*Erythroxylon coca*) at Peradeniya, Ceylon, in April 1914, the bright green colour of the bugs approximating closely to that of the leaves of the tree on which they were resting.

We have this insect also from Yercaud, in the Shevaroy Hills. In the present case it occurred on Coca at Peradeniya in sufficient numbers to constitute a pest.

96. Early stages of Stephanitis typicus, Dist.

The figure shows the stages in the lifehistory of *Stephanitis typicus*, the illustrations having been drawn from individuals in different stages of development but all found together at one time. So far it has not proved practicable to follow up the lifehistory in detail but the various stages are figured in sufficient detail for economic purposes.

The eggs are thrust into tissues of a leaf of the foodplant (usually Plantain) either singly or more frequently in groups. The numbers actually counted in five such groups were 23, 37, 44, 67 and 91. The opening made by the ovipositor of the female when egglaying becomes ringed with white, whilst the cavity in which the egg is actually embedded turns black, so that the places where eggs have been deposited become readily apparent when search is made with a lens.

The young bugs and adult insects are dull whitish in colour and very inconspicuous against the whitish bloom present on the leaves of some varieties of plantain. They are rarely found on the upper surface of the leaf but feed almost exclusively on the lower surface, which they puncture especially along either side of the mid-rib, producing a spotted appearance of the leaf which presently looks unhealthy and loses the glossy appearance characteristic of healthy tissue.

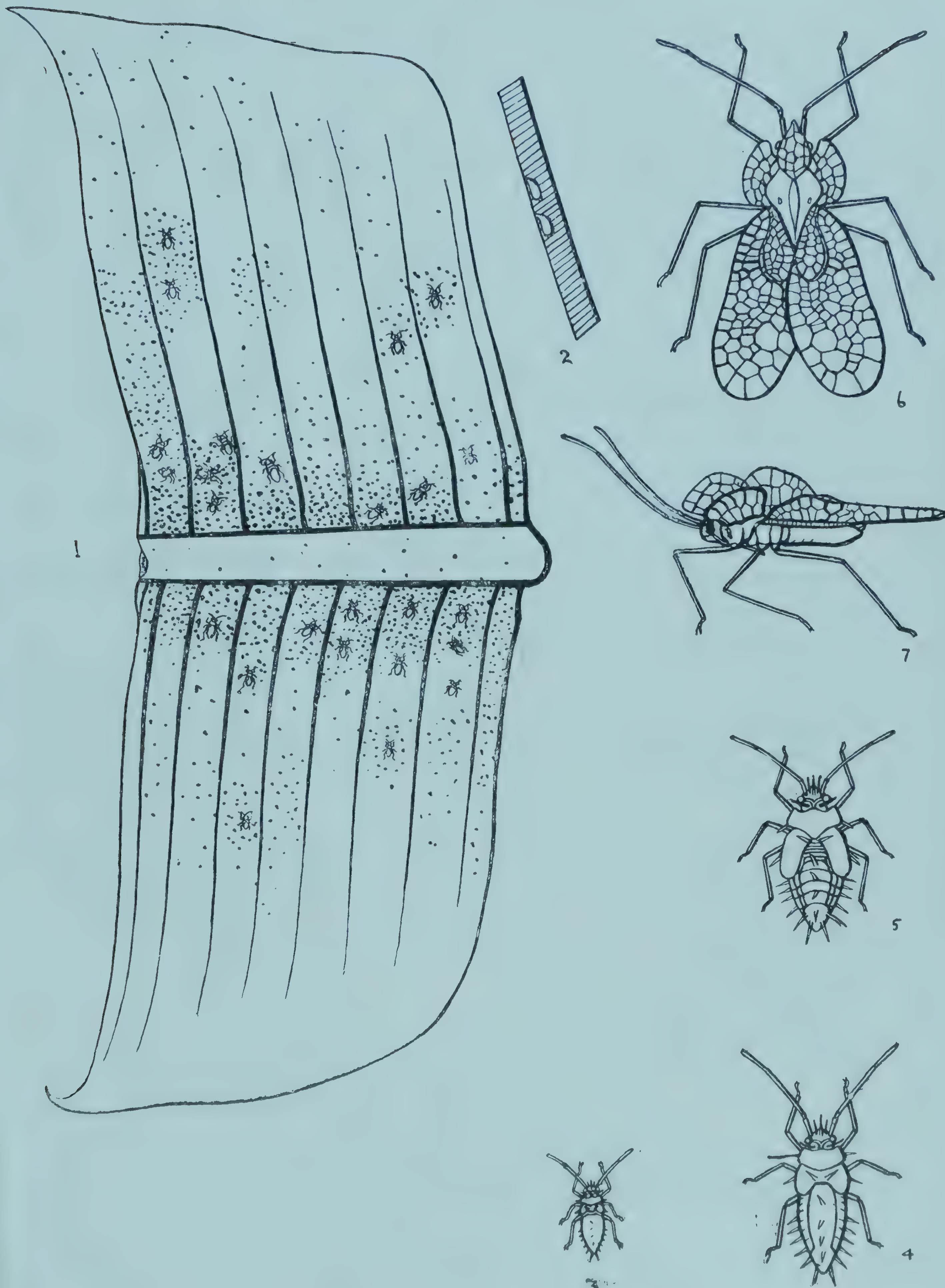

Fig. 20. *Stephanitis typicus.*
(Fig. 1 is natural size ; the other figures are magnified.)

97. Sugarcane Hoppers.

The identity of Sugarcane Hoppers in India has become greatly confused and a note on the present state of our knowledge may be useful.

In *Indian Museum Notes,* Vol. V, page 43 (1900), a hopper destructive to cane in the North Arcot District is referred to under the name of *Dictyophara pallida ;* this note probably refers to *Pyrilla perpusilla* wholly or in part.

In *Indian Insect Pests,* page 134, and *Entom. Memoirs Dept. Agric. India,* Vol. I, page 240, Lefroy used the name *Dictyophara pallida* to indicate a cane-hopper which is probably really a species of *Pyrilla.*

In *Indian Insect Life,* page 727, Lefroy stated that " *Pyrilla* (*Zamila*) *aberrans,* Wlk., (*lycoides,* Wlk.) has been confused with *Dictyophara pallida,* Don., in *Indian Museum Notes* and other publications. It is an important pest to Cane ..... (and) ..... is found practically throughout India." The figure (Fig. 500) given here apparently represents *P. perpusilla,* and it may be noted that *aberrans,* Wlk., is a distinct species from *lycoides,* Wlk., which is Siamese and not Indian at all, unless it proves to occur in Burma.

Specimens found at Pusa have been identified by Mr. Distant as *Pyrilla aberrans, P. perpusilla,* and *P. pusana,* the last being a novelty described in *Ann. Mag. Nat. Hist.* (8) XIV, p. 326 (October 1914), so that we have three distinct forms of *Pyrilla,* all occurring in one locality. These three forms are extremely close to one another and not easy to discriminate and it is possible that they may be shown to intergrade. Long series of hoppers, from all the cane areas of India and taken at different seasons of the year, are required to establish the specific validity of these forms.

98. Indian Aleyrodidae.

In Technical Bulletin No. 27 of the United States Bureau of Entomology, Messrs. Quaintance and Baker have lately discussed the classification of the described Aleyrodidæ (Aleurodidæ) of the World. As the Indian species are very little known and have been greatly neglected, although some are of considerable economic importance, it may be useful to Indian workers to give a list of all species known from the Indian Region (including Ceylon), extracted from the above publication. Those species marked * are known to be of some economic interest.

* *Dialeurodes citri,* Riley and Howard. (India, China, Japan, etc. on *Citrus* and *Jasminum* spp.)

* *D. eugeniæ,* Mask. (India ; on *Eugenia.*)

Aleuroplatus alcocki, Peal. (Calcutta ; on *Ficus indica.*)

A. hoyæ Peal. (Calcutta ; on *Hoya* sp.)

A. quaintancei, Peal. (India ; on *Ficus religiosa*.)
Pealius bengalensis, Peal. (India ; on ?)
Bemisia leakii, Peal. (India, Fiji ; on Indigo.)
B. religiosa, Peal. (India ; on *Ficus*.)
Aleyrodes cotesii, Mask. (Baluchistan ; on Rose.)
Aleurocanthus bambusæ, Peal. (India ; on bamboo.)
* *A. nubilans*, Buckt. (India ; on betel leaves (*Piper betle*).)
* *A. piperis*, Mask. (Ceylon ; on pepper.)
* *A. spiniferus*, Quaint. (India, Java ; on *Citrus*.)
* *Neomaskellia bergi*, Sign. (India, Java, Philippines, Mauritius, etc., on cane.)
* *Aleurolobus barodensis*, Mask. (India ; on cane.)
A. simula, Peal. (India ; on *Bombax malabaricum*.)
Asterochiton vaporariorum, West. (India ; cosmopolitan.)

Specimens of all species are required at Pusa in order to obtain further information concerning distribution and range of foodplants of these insects in India.

99. Food of Liogryllus bimaculatus.

In *South Indian Insects* (page 537) I have noted as regards the food of *Liogryllus bimaculatus*, the large black yellow-spotted cricket, that it " probably feeds on decaying vegetation ; possibly predaceous on other insects." In March 1915 specimens were collected at Pusa in a gram-field infested with larvæ of *Agrotis ypsilon* and it was found that in confinement these crickets fed on both ripe gram-pods, climbing up the plants and biting a hole through the capsule and eating the seeds, and on living larvæ of *Agrotis ypsilon*. They seemed to prefer a mixed diet, eating both gram-pods and larvæ when both were provided.

100. Coptotermes gestroi in India.

Coptotermes gestroi was originally described by Wasmann from Burma. The Pusa collection contains specimens, identified by Professor N. Holmgren as *C. gestroi*, from Assam.

Coptotermes gestroi has earned an unenviable notoriety in economic literature as destructive to Rubber-trees in the Malay Peninsula, but it is probable that the Malayan species is *Coptotermes curvignathus*, Holmgr. (Termitenstudien IV 77) which is the *gestroi* of Haviland and Bugnion but not of Wasmann. *C. curvignathus*, Holmgr., is known from the Malay Peninsula, Singapore, Borneo and Burma.

PUSA,
September, 1915.

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